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EDMONTON COAL RESEARCH LABORATORY

KILBORN PROJECT NO. 7814-15

CHARACTERISTICS OF CANADIAN MAGNETITE RESOURCES FOR OPTIMUM UTILIZATION IN COAL HEAVY MEDIA PROCESSES

REPORT ON

SURVEY OF MAGNETITE MEDIUM USAGE IN HEAVY MEDIA COAL CLEANING

SUBMITTED BY:

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MICROMEDIA

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February 7, 1986

Edmonton Coal Research Laboratory
CANMET
One Oil Patch Drive
Devon, Alberta
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Attention: Mr. M. W. Mikhail
Project Scientific Authority

Dear Sirs:

Please find enclosed fifteen (15) copies of the Report entitled:

'SURVEY OF MAGNETITE MEDIUM USAGE IN HEAVY MEDIA COAL CLEANING'

which is submitted to you as the conclusion of Phase I of the current Project:

'CHARACTERISTICS OF CANADIAN MAGNETITE RESOURCES FOR OPTIMUM UTILIZATION IN COAL HEAVY MEDIA PROCESSES.'

We hope that this Report meets with your satisfaction and if further, more specific information is required either immediately following your receipt of this Report or later as the Project proceeds, please note that we will be maintaining a 'hard copy' file of useful technical information including references which is available to you as required.

Yours truly,

KILBORN ENGINEERING (B. C.) LTD.

fr R. J. Davies, P.Eng.
Project Manager

RJD/mr
Enclosure

143pp

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1.0 INTRODUCTION

1.0 INTRODUCTION

Kilborn Engineering (B. C.) Ltd. (Kilborn) has been contracted to carry out a survey of magnetite medium usage in heavy media coal cleaning. This study is the first phase of a Project designed to investigate the characteristics of Canadian magnetite resources for optimum utilization in coal heavy media processes. This work was awarded by the Department of Supply and Services on behalf of the EMR CANMET, Edmonton Coal Research Laboratory which is located in Devon, Alberta.

Canada is a comparative newcomer in utilizing heavy media coal cleaning systems. The first coal preparation plants built in Canada, which incorporated heavy media systems, were completed in the late sixties and early seventies. This technology was brought to Canada from Europe and the U.S.A., and during the seventies five new plants were constructed employing heavy media bath and cyclone separation. In almost every case, expensive lessons were learned by these pioneering operators, unfamiliar with operating requirements and having to cater for excessively large amounts of very fine coal or severe clay problems which frequently caused serious operating difficulties.

Since the beginning of the 1980's, several new plants incorporating heavy media circuits have been designed and built. Most have incorporated changes from the first generation plants but up to now very little operational research into magnetite media properties in particular, has been carried out and there is much room for investigation and a specific program of development.

The Edmonton Coal Research Laboratory of EMR CANMET has undertaken an increasing amount of work which has comprised much industry based measurement of the performance of operational plants. It has progressively equipped its Laboratories and Pilot Plant with laboratory and pilot scale equipment together with the necessary tests and analytical equipment. These facilities now rank amongst the best in the world.

Although much as been done to measure and improve plant performance, one area which has, so far, not received specific attention is the use of magnetite as a media in coal cleaning processes. In fact very little research and development work relating to the use of magnetite as a media in coal preparation is currently being undertaken in Canada and yet this application is a vital one to Canada's current export market in two different and important ways; domestic use in producing export coal; and for export of prepared magnetite.

Most of the coal exported from Canada at the present time, is produced by treatment plants employing heavy media (magnetite suspension) systems. This represented approximately 16 million tonnes of coal in 1982 using approximately 50,000 tonnes of magnetite costing some $3 million. Kilborn has forecast that by 1988, magnetite consumption could have increased by 100 percent above the 1982 figure, and by 1995 by a further 100 percent, based upon new projects being developed and significant expansion of existing coal mines.

Most operators in the Canadian Coal Industry are known to be actively seeking technical solutions which will lead to a marked reduction in consumption. Consumption in Canadian plants is known to be significantly higher than that reported by European, Australian and South African operators.

Canada now joins several other major coal producing countries in attempting to develop a detailed specification for magnetite to ensure a favorable balance between cost and technical effectiveness in its use for coal cleaning. Nevertheless, specifications for magnetite are still loose and unscientific. Only the percentage of material passing through a 50 micron sieve, the percentage of magnetic content, and the percentage of moisture, are contracted requirements between supplier and user. With such loose requirements, the quality of supplied magnetite is reportedly inconsistent and often falls outside of this specification.

Countries outside of Canada, especially those involved in exporting coal, are known to be actively investigating the scientific needs for magnetite specification. Known ongoing research and development is, at present, being conducted by scientists and engineers at the following centres:

(a) Australian Coal Industry Research Laboratories in Australia;
(b) Mining Research and Development Establishment/NCB in Britain;
(c) Steinkohlenbergbauverein and Saarbergwerke AG in West Germany;
(d) Department of Energy/USBM in the U.S.A.:
(e) National Institute for Coal Research in South Africa;
(f) Dutch State Mines/STAMICARBON in Holland.

This latter work is an extension of the work program commenced 40 years ago by Dutch State Mines in Holland who have probably contributed more than any other single organization towards the design of heavy media coal cleaning and recovery processes.

Although no national or internationally approved standard specifications have yet been published in any of the above countries, all have set down a code of practice. They have also all contributed to the current ISO Draft Proposal 8833 which is scheduled for issue as an approved standard during 1986.

Magnetite has an impact on Canada's export market as an export product in its own right. The Canadian Coal Industry is concerned that current sources of supply are vulnerable to closure and could terminate at any time without warning. This would leave the industry short of magnetite which is in effect, the 'lifeblood' of coal cleaning plants. This is a problem which in itself must be solved soon. Australia has recently imported magnetite from British Columbia for use in its own coal industry. Their growth rate in the last few years has made them very dependent upon B. C. supply, which is acknowledged as much superior in quality to their own indigenous sources of supply. It is believed that at least 70 percent of Australia's 80,000 tonnes of magnetite consumed in 1981 was imported from Canada. Australia produced over 90 million tonnes of coal of which over half was cleaned by heavy media plants. In 1982, Canada started exporting small quantities of magnetite to the

U.S.A. This market could be expanded if American users receive a competitively priced and technically superior product from Canada.

The problem remains, to identify potential sources of supply which are suitably located geographically to be able to contemplate supplying the needs of the coal industry (at home and abroad) in a cost effective manner. In the early 1980's, there were only five magnetite producing iron ore mines in Canada (four of these in eastern Canada) and four potential sources of supply from base metal producers (all in western Canada) including the two actual sources of supply of heavy media grade magnetite, Craigmont (B. C.) and Westfrob (B. C.). The proven reserves of these two coal media magnetite suppliers have been estimated at being well below one million tonnes in total.

This survey is intended to cover the following areas:

(a) magnetite sources and reserves in Canada;
(b) magnetite usage in heavy media coal cleaning;
(c) utilizable properties of magnetite for the application in coal cleaning heavy media processes;
(d) methods for testing and evaluation of the properties of magnetite.

The survey is regarded as being the prelude to a Project for the Edmonton Coal Research Laboratory of CANMET, for the determination of characteristics of Canadian Magnetite resources with the objective of determining the optimum utilization in coal heavy media processes.

2.0 SUMMARY

2.0 SUMMARY

Perhaps the most significant development in terms of the application of magnetite for heavy media coal cleaning has been the production of the draft ISO Standard, DP 8833, for the 'Testing of Magnetite for Use in Coal Preparation'.

With the emergence of this document as a firm standard later in 1986, there will be, for the first time, an internationally agreed approach to the identification of the essential requirements of a magnetite for use in heavy media coal cleaning. There will also be a definition of suitable methods for testing this material.

The tests specified in this International Standard will assist the user in the selection of magnetite and provide a basis for quality control testing. However, no attempt has been made to formulate the requirements for specific applications.

These specified tests will ensure that the properties which make magnetite suitable for heavy media coal cleaning purposes are effectively tested. These properties are:

(a) Moisture content, as received, %.
(b) Particle size distribution, microns.
(c) Ferro magnetics content, %.
(d) Relative density, $g.cm^3$.
(e) Total iron content, %.
(f) Ferrous iron content.
(g) Fundamental magnetic properties.

All of these properties may require testing for the detailed assessment of a new source of magnetite, but for routine checking of regular supplies only, (a), (b), (c) and (d) should be necessary.

In broad terms, the generally accepted, preferred specification for heavy media grade magnetite is still that which was laid down many years ago by the National Coal Board (NCB) in Britain, i.e.:

(a) Relative density shall not be less than 4.85.
(b) Magnetic content shall not be less than 97 percent.
(c) The size fraction below 60 micron shall not be less than 85 percent by weight.
(d) The size fraction below 10 micron shall not exceed 25 percent by weight.
(e) Moisture content at the time of shipment shall not exceed 10 percent.
(f) Chemical composition shall in no way render it hazardous to operators, or unsuitable in any other way.

Items (a) to (d) are determined on a dry basis.

Most countries employ a specification similar to that of the NCB, but in some areas, especially where sources of supply are limited, e.g., in western Canada, some relaxation is tolerated in exchange for a favourable selling price.

Canada has plentiful deposits of useable magnetite, many of which are located in reasonably close proximity to the coal fields. It is, therefore, most unlikely that user companies will need to consider the alternative of long-term importation even in eastern Canadian coal fields. The current situation in western Canada, whereby much of the magnetite originates from one source, is unlikely to be perpetuated for much longer. The magnetite reserves of this producer limit its capability to supply on a long-term basis and other sources of supply will eventually appear as the selling price becomes more favourable to the supplier. At present, heavy media grade magnetite is available directly from stockpile and production costs are very low. Within the next few years, as existing stocks become depleted, production cost increases will undoubtedly cause the selling price to rise to cover the cost of mining, crushing, milling and beneficiation, especially for sources with potentially low transportation costs.

Some countries employ in-plant magnetite preparation, including milling, e.g., South Africa and Britain, in order to ensure that the heavy media suspension is always in close compliance with the specified needs of a particular type of washing unit. Other countries appear to dictate firmly to suppliers the specified needs determined for their heavy media circuits, e.g., U.S.A. and Australia. Various grades of heavy media are available, their differences in selling price reflecting the degree of milling and beneficiation carried out to obtain the product.

The organizations which appear at present to be the most actively engaged in research into magnetite for heavy media coal cleaning are ACIRL of Australia, Mintek of South Africa, and the Pittsburgh Energy Technology Center of the U.S. Department of Energy. Other organizations are working in specific areas of heavy media testing and performance evaluation, including the NCB of Britain, Saarbergwerke AG of West Germany, Stamicarbon of the Netherlands, and Penelec of the U.S.A. Some work is also being conducted into the use of fly ash derived heavy media material by the Ames Laboratory in the U.S.A. and CANMET in Canada.

Poor loss control rather than substandard magnetite quality would appear to be the principal cause of high magnetite consumption in many Canadian plants at the present time. Heavy loss appears to be the result of coal flow surges in the heavy media circuit created in most cases by poor raw coal blending and feeding or bad distribution to multi-stream circuits. Few of Canada's plants are suitably equipped to carry out more than very basic analysis or testing of magnetite and much of the testing which is done is simplistic and non-quantitative when compared to practices in other major coal exporting countries, i.e., Australia and South Africa.

3.0 MAGNETITE RESOURCES AND RESERVES IN CANADA

3.0 MAGNETITE RESOURCES AND RESERVES IN CANADA

3.1 CURRENT SOURCES OF SUPPLY IN CANADA

Coal mines located in western Canada, e.g., western Alberta and British Columbia which have heavy media coal preparation plants, have until recently, acquired magnetite from either one or both of the following sources:

(a) Craigmont Mines, Merritt, B. C.;
(b) Westfrob Mines, Tasu, B. C.

Both are defunct copper mines at which a magnetite product was milled and stored in ponds mainly to supply the needs of the coal industry. Since mid-1984, Westfrob has ceased magnetite sales and Craigmont alone now provides for the entire Pacific Northwest including a plant in Washington State.

Only one coal mine in eastern Canada requires magnetite, that at Victoria Junction in Nova Scotia belonging to Cape Breton Development Corporation (DEVCO). DEVCO has in the past purchased magnetite from Canadian sources but has also had to obtain supplies from overseas (Sweden, South Africa) and from the U.S.A. At present, the plant is using magnetite from the Tawahus mine in New York purchased through National Lead and Chemical Company of New Jersey.

3.2 OTHER POTENTIAL SOURCES OF SUPPLY

Figure 3-1 shows the locations of all major iron ore deposits containing magnetite which have operated at some time during the past decade together with other mines which treat ores containing magnetite, such as base metal producers. Table 3.01 provides a listing of the mines shown in Figure 3-1.

It is known that several small magnetite deposits are being reviewed for their economic viability at the present time. These are mainly located in B. C. and the Yukon. Also, there are a number of larger mining operations that have accumulated large secondary (tailings) deposits containing magnetite which are at present examining the potential for retreatment including upgrading to meet the specification for the coal heavy media application. Included in these are Island Copper in Port Hardy, B. C., Cassiar Mining Corporation in Cassiar, B. C. and the now defunct Whitehorse copper mine in the Yukon.

A number of potential new magnetite sources, i.e., potential new mines, exist in reasonably close proximity to the western coal fields, but it is evident from discussions with the potential mine developers that none would be motivated toward starting up operations purely by the heavy media demand. Most view this market as a potentially lucrative byproduct and all regards current selling prices as being too low for economic justification. The majority of potential new mines in British Columbia would be dependent upon copper and precious metals production. Examples are Searchlight Resources, Iron River prospect at Campbell River on Vancouver Island, the new Texada Island prospect, and deposits at Tullomeen and Falcon. For such operations, magnetite preparation for the heavy media application will require a special treatment circuit, an example of which is shown in Figure 3-2.

The potential for recovering magnetic iron from byproducts or waste residues has also been examined. Inco Limited has an iron ore recovery plant at Copper Cliff, Ontario which treats a complex iron silicate slag to produce iron oxide pellets by leaching, reduction and pelletizing processes. Small quantities of magnetite iron ore also known to be produced at the Cominco smelter in Trail, B. C. Neither source has yet been used as a source of coal washing heavy media, although both appear to have been considered at some time in the past. In the U.S.A., the use of magnetically separated coal fly ash derived media has recently been carefully examined and a similar study is under in eastern Canada with fly ash from the combustion of high sulphur containing New Brunswick coals.

3.3 OTHER SUPPLIERS TO CANADIAN USERS

DEVCO's Victoria Junction plant has purchased magnetite from a number of foreign sources. These have included Kiruna, Sweden and Palaborwa, South Africa but the majority of the imported magnetite has come from the eastern U.S.A. Table 3.02 lists some of the current American sources of supply.

3.4 MAGNETITE DEMAND FOR HEAVY MEDIA USAGE

Edmonton Coal Research Laboratory, assisted by Kilborn, will be conducting a nationwide survey of magnetite consumption for heavy media usage as part of the current Project. It is hoped that detailed information regarding consumption, sources of supply and current cost will be obtained from this survey. Table 3.03 gives the results of a recent private survey for western Canada which contained a large amount of estimated data. The current level of consumption for British Columbia and Alberta would appear to be between 70-75,000 tonnes per year with a future potential for increasing to about 100,000 tonnes by 1990.

TABLE 3.01

SOURCES OR POTENTIAL SOURCES OF MAGNETITE IN CANADA

Mine or Producer	Location	Principal Ore Value(s)	Magnetite Concentrate Grade Fe %	SiO$_2$ %	% -325 Mesh	Products Shipped	Status
Adams Mine	Kirkland Lake Ont.	Magnetite	66	5	92	Pellets	Operated Dofasco
Griffith Mines	Bruce Lake, Ont.	Magnetite	69	NK	90	Pellets	Closed
Hilton Mine	Quebec	Magnetite	66	2.2	75	Pellets	Closed
Carol Lake	Labrador	Hematite/ Magnetite	67	NK	65	Pellets and Concentrate	Operated IOCC
Marmoraton	Marmorn, Ont.	Magnetite	66	NK	65	Pellets	Closed
Moose Mountain	Sudbury, Ont.	Magnetite	65.5	8	75-97	Pellets	Closed
Sherman	Temagami,Ont.	Magnetite	67.5	5	55-65	Pellets	Operated Dofasco
Westfrob	Queen Charlotte (Tasu) B. C.	Magnetite	69.0	NK	90-95	Pellets and Concentrate	Closed
Byproduct							
Inco Limited	Sudbury, Ont.	Pyrrhotite	67	2	NK	Pellets and Concentrate	Operated Inco
Texada	Gillies Bay Texada, B. C.	Copper Sulphides Magnetite	64.5	NK	70	Coarse and Fine Concentrate	Closed
Craigmont	Merritt, B. C.	Copper/Magnetite Sulphides	65-68	3	90	Copper and	Mine Closed Magnetite sales
Island Copper	Port Hardy, B. C.	Copper/Moly Precious Metals				Copper/Moly Concentrates	Operated Utah Mines
Whitehorse Copper	Whitehorse, Yukon	Copper Sulphides	68.5	1	+90	Copper Concentrates	Closed
Cassiar	Cassiar, B. C.	Crysatile Asbestos	NK	NK	NK	Asbestos Fibre	Operated Cassiar Mining Corp.

Note: NK is 'not known'.

TABLE 3.02

U.S.A. SOURCES OF HEAVY MEDIA GRADE MAGNETITE

			Quality Offered			
Company	Location	Source	Fe %	SiO_2 %	Magnetics	% - 325 Mesh
Foote Mineral	Exton Pennsylvania	NK	62	1.5	91 - 94	92
Novacor	Minnesota	NK	NK	NK	NK	NK
American Vermiculite	NK	NK	64	1.0	88	96
National Lead & Chemical	Tawahus New York	NK	NK	NK	NK	NK
Reiss Viking Corporation	Tazewell West Virginia	Magnetite Tailings	63	1.5	91	95
Prince Manufacturing	Bowmanstown Pennsylvania	NK	NK	NK	NK	NK

Note: NK is 'not known'.

TABLE 3.03

SURVEY OF MAGNETITE DEMAND AND USAGE: WESTERN CANADA

MINE		CURRENT STATUS	PROVINCE		ANNUAL CLEAN-COAL TONNAGE MTPA	PROPORTION OF RAW COAL TREATED BY HEAVY MEDIUM	ESTIMATED MAGNETITE CONSUMPTION kg per clean coal tonnage		ANNUAL MAGNETITE USAGE METRIC TONS	CURRENT SUPPLIER	TRANSPORT TO MINE BY	GENERAL REMARKS	PLANT STATUS
NAME	OPERATOR	OPERATING	B.C.	ALTA.			AS STATED	ESTIMATED					
ELKVIEW	WESTAR MINERALS	from 1970	✓	-	7.5	70-75	2.3 (5)	2.3 (5)	17,250	CRAIGMONT	RAIL	METALLURGICAL COAL (SMALL AMOUNT OF THERMAL) TRIED WESTFROB	FIRST GENERATION PLANTS
CARDINAL RIVER	LUSCAR/CONSOL	from 1970	-	✓	3.5	70-75	0.9 (2)	1.4 (3)	4,900	CRAIGMONT	ROAD	METALLURGICAL COAL	
COAL VALLEY	LUSCAR/STERCO	from 1977	-	✓	3.5	70	1.4 (3)	1.8 (4)	6,300	CRAIGMONT	ROAD-BULK	PURCHASED FROM WESTFROB IN 1980/1 BUT QUALITY PROVED UNACC	
ELKFORD	FORDING COAL	from 1972	✓	-	3.5	65-75	- -	2.7 (6)	9,450	CRAIGMONT	RAIL	METALLURGICAL COAL & SMALL BUT GROWING THERMAL TONNAGE	
SMOKEY RIVER	McINTYRE	from 1970	-	✓	1.5	60-70	1.8 (4)	2.3 (5)	3,450	CRAIGMONT	ROAD/RAIL	METALLURGICAL COAL	
								TOTAL	41,350				
LINE CREEK	CROWS NEST RES.	from 1982	✓	-	3.5	30-70	- -	1.8 (4)	6,300	N/A	RAIL	TWO PLANTS 1 FOR THERMAL 1 FOR METAL BOTH H MEDIUM	SECOND GENERATION PLANTS
GREGG RIVER	MANALTA	from 1983	-	✓	2.0	70-75	1.4 (3)	1.8 (4)	3,600	CRAIGMONT	N/A	METALLURGICAL COAL	
GREEN HILLS	WESTAR MINING	from 1983	✓	-	2.0	70-75	1.4 (3)	1.8 (4)	3,600	N/A	RAIL	METALLURGICAL COAL	
QUINTETTE	DENISON MINES	from 1983	✓	-	6.5	70-75	1.8 (4)	1.8 (4)	11,700	CRAIGMONT	RAIL	TWO PLANTS 1 FOR THERMAL 1 FOR METAL BOTH H MEDIUM	
BULLMOOSE	TECK CORP.	from 1983	✓	-	1.7	70-75	- -	1.8 (4)	3,060	N/A	RAIL	METALLURGICAL COAL	
BYRON CREEK	ESSO RES.	from 1986	✓	-	2.0	65-75	- -	1.8 (4)	3,600	N/A	RAIL	THERMAL COAL	
								TOTAL	31,860				
								COMBINED	73,210				
MT. KLAPPAN	GULF	x	✓	-	1.5	N/A	- -	1.8 (4)	2,700	N/A	N/A	ANTHRACITE OPEN PIT	THIRD GENERATION PLANTS
MONKMAN	PETRO CANADA	x	✓	-	3.0	N/A	- -	1.8 (4)	5,400	N/A	N/A	METALLURGICAL COAL OPEN PIT	
BELCOURT	DENISON MINES	x	✓	-	5.0	N/A	- -	1.8 (4)	9,000	N/A	N/A	METALLURGICAL COAL OPEN PIT GULF PARTNER	
SAXON	DENISON MINES	x	✓	-	4.0	N/A	- -	1.8 (4)	7,200	N/A	N/A	METALLURGICAL COAL OPEN PIT - UNDERGROUND	
COALSPUR	DENISON MINES	x	-	✓	3.0	N/A	- -	1.8 (4)	5,400	N/A	N/A	THERMAL COAL - EXPORT	
ELK RIVER	ELCO MINING	x	✓	-	4.0	N/A	- -	1.8 (4)	7,200	N/A	N/A	METALLURGICAL COAL	
SUKUNKA	B.P. CANADA	x	✓	-	1.0	70-75	- -	1.8 (4)	1,800	N/A	N/A	METALLURGICAL COAL - EXPORT	
SHAUGHNESSY	FORDING COAL	x	-	✓	2.0	N/A	- -	1.8 (4)	3,600	N/A	N/A	THERMAL COAL - EXPORT	
TELKWA	CROWS NEST RES.	x	✓	-	1.0	N/A	- -	1.8 (4)	1,800	N/A	N/A	THERMAL COAL - EXPORT	
McLEOD RIVER	MANALTA	x	-	✓	4.0	N/A	- -	1.8 (4)	7,200	N/A	N/A	THERMAL COAL - EXPORT	
CARBON CREEK	CARBON CREEK	x	✓	-	2.0	N/A	- -	1.8 (4)	3,600	N/A	N/A	METALLURGICAL/THERMAL COAL - EXPORT	
								TOTAL	48,420				

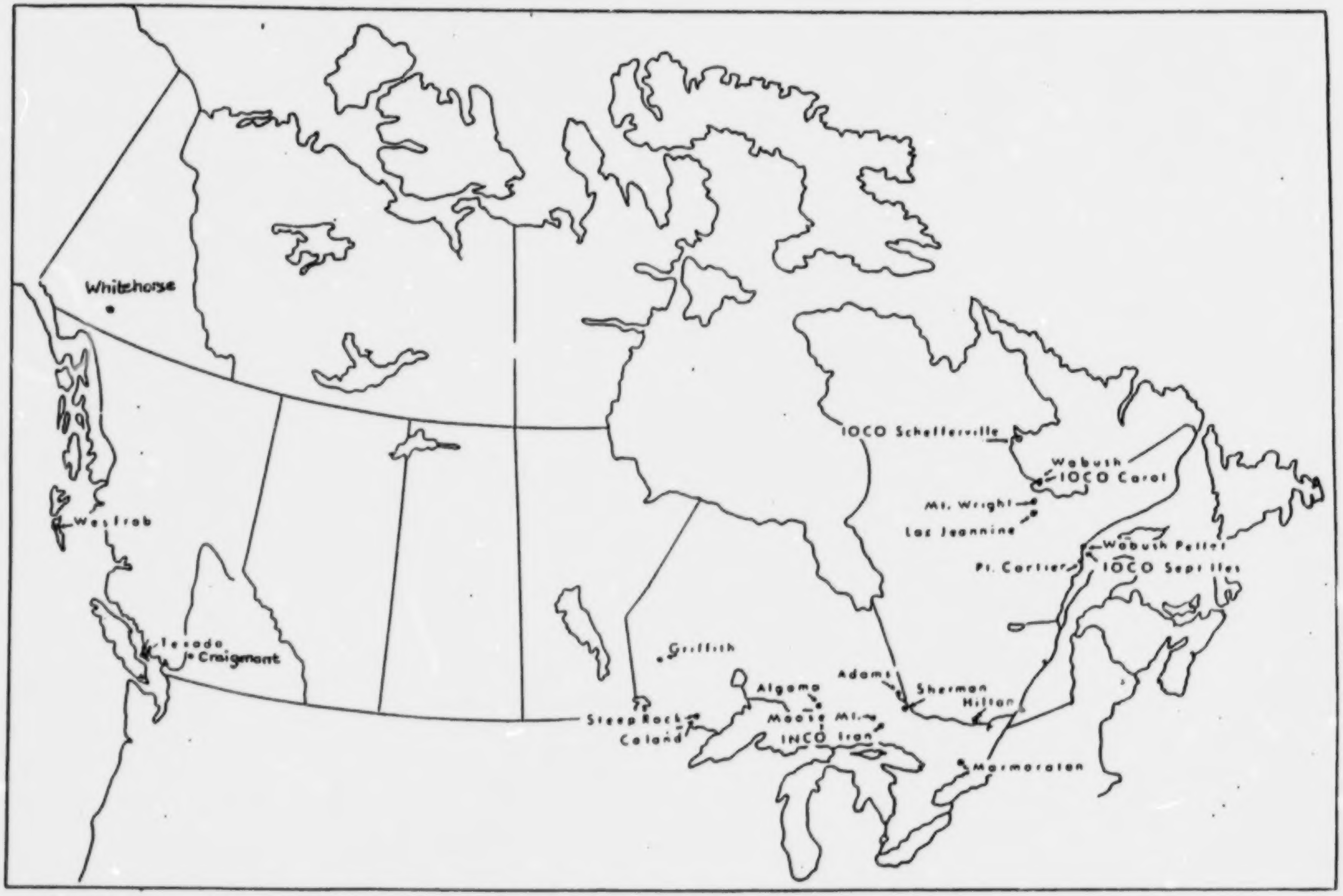
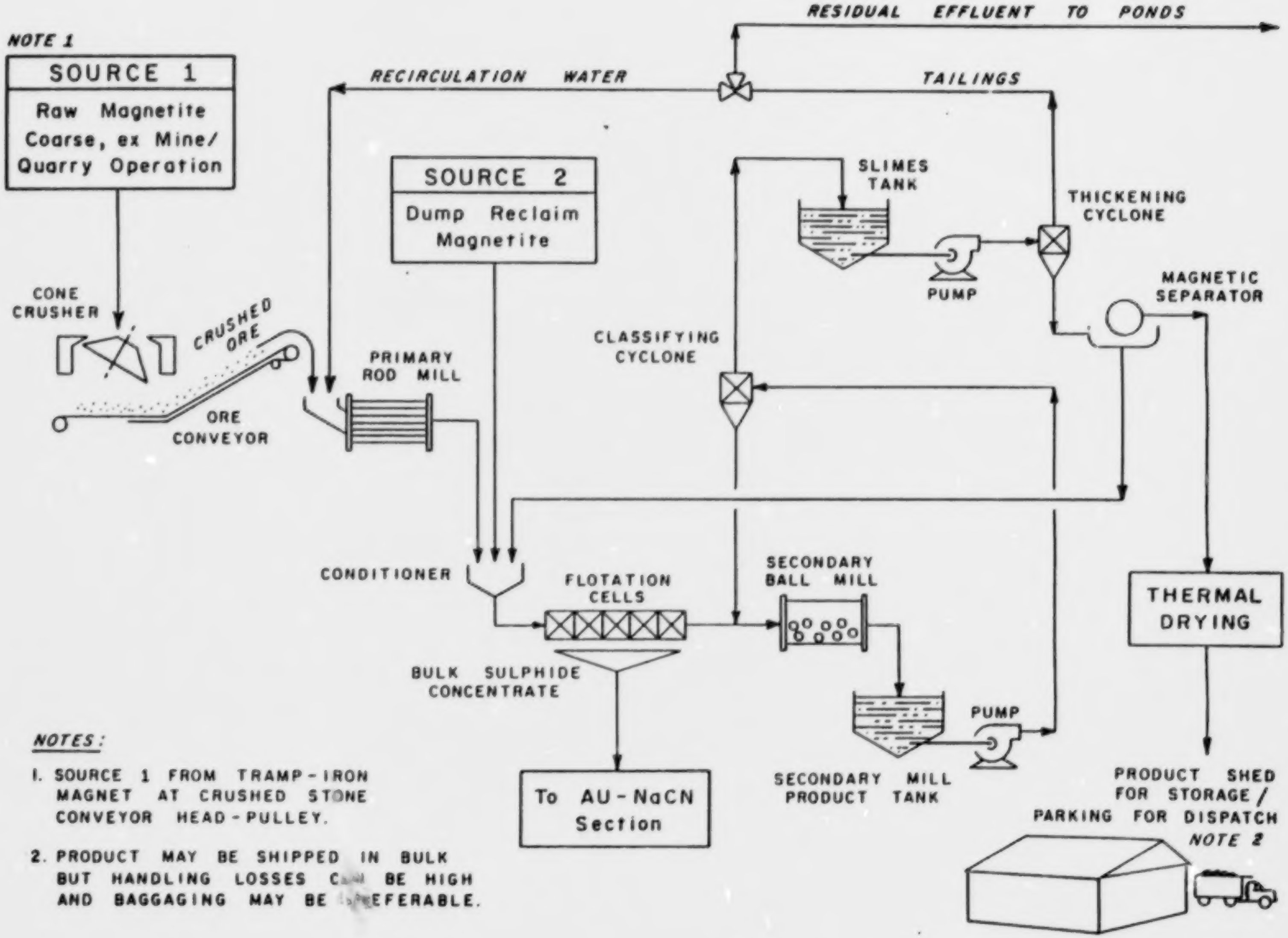

Whitehorse
Westfrob
Texada
Craigmont
Griffith
Steep Rock
Caland
Algoma
Moose Mt.
INCO Iron
Adams
Sherman
Hilton
Marmoraton
IOCO Schefferville
Wabush
IOCO Carol
Mt. Wright
Lac Jeannine
Wabush Pellet
Pt. Cartier
IOCO Sept Iles

FIGURE 3-1: MAP SHOWING LOCATIONS OF ALL MAJOR IRON ORE DEPOSITS IN CANADA


NOTE 1
SOURCE 1
Raw Magnetite Coarse, ex Mine/ Quarry Operation
SOURCE 2
Dump Reclaim Magnetite
RECIRCULATION WATER
RESIDUAL EFFLUENT TO PONDS
TAILINGS
CONE CRUSHER
CRUSHED ORE
ORE CONVEYOR
PRIMARY ROD MILL
SLIMES TANK
PUMP
THICKENING CYCLONE
MAGNETIC SEPARATOR
CLASSIFYING CYCLONE
CONDITIONER
FLOTATION CELLS
BULK SULPHIDE CONCENTRATE
SECONDARY BALL MILL
To AU-NaCN Section
SECONDARY MILL PRODUCT TANK
PUMP
THERMAL DRYING
PRODUCT SHED FOR STORAGE / PARKING FOR DISPATCH
NOTE 2

NOTES:

1. SOURCE 1 FROM TRAMP-IRON MAGNET AT CRUSHED STONE CONVEYOR HEAD-PULLEY.
2. PRODUCT MAY BE SHIPPED IN BULK BUT HANDLING LOSSES CAN BE HIGH AND BAGGAGING MAY BE PREFERABLE.

FIGURE 3-2: EXAMPLE OF A HEAVY MEDIA MAGNETITE PREPARATION CIRCUIT

REFERENCES - SECTION 3.0

D. Abott — 'Preparation of a High Specific Gravity Concentrate from the Iron-Rich Fly Ash of the Minto Coal - New Brunswick.' Report AS/84/21, Research & Productivity Council, November, 1983.

R. G. Aldrich — 'Separation of High Grade Magnetite from Fly Ash.' U.S. Patent No. 4,432,868, February 21, 1984.

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G. Hawthorn — 'Craigmont Mines Limited' pp. 93-95.
C. M. Brown, et al — 'Utah Mines Limited - Island Copper Mine, pp. 127-129.

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D. Linzey — 'Whitehorse Copper Mines Ltd.', pp. 130-132. Milling Practice in Canada.

D. Mita, M. J. Murtha, and G. Burnet — 'Comparative Studies of Magnetite and Magnetically Fractioned Fly Ash Heavy Media for

W. H. Muloin — 'Processing of Iron Ores' in Milling Practice in Canada. CIMM, pp. 233-291, 1978.
'Milling of Copper and Copper Molkybdenum Ores' also in Milling Practice in Canada.

Use in Coal Washing.' Proceedings - 6th International Ash Utilization Symposium, Reno, 1982.

4.0 MAGNETITE USAGE IN COAL CLEANING

4.0 MAGNETITE USAGE IN COAL CLEANING

4.1 TYPICAL OPERATING CIRCUITS

The heavy media coal cleaning circuits in Canadian coal preparation plants can be sub-divided into two groups:

(a) Those cleaning coarse coal, i.e., heavy media baths; e.g. 100 mm by 10 mm;
(b) Those cleaning small coal sized plus 0.5 millimeters i.e. heavy media cyclones.

In a recent report prepared by CMRC for presentation to the International Organizing Committee for the International Coal Preparation Congress, the flowsheets of every Canadian coal preparation plant are supplied and described. Table 4.1-1 is extracted from this report and summarizes the plants containing heavy media circuits. In western Canada, an almost standard heavy media flowsheet has emerged for the treatment of Rocky Mountain low volatile bituminous coking coals. This comprises:

(a) Heavy media bath;
(b) Heavy media cyclones;
(c) Double stage water-only cyclones;
(d) Froth flotation.

In some cases, the raw coal is so finely sized when delivered to the preparation plant, that there is insufficient sized above 10 millimetres to justify the installation of a heavy media bath circuit. In such cases, the upper size fed to the heavy media cyclones will be coarser (up to 50 millimetres in size) although the mean grain size of the actual feed may still be very fine, for example: Quintette 8 mm by 0.5 mm fraction = 1.8 mm; Balmer 6.35 mm by 0.5 mm fraction = 1.88 mm; and Byron Creek 6.5 mm by 0.5 mm fraction = 1.67 mm.

Heavy media cyclone circuits can be sub-divided into two categories:

(a) pump fed;
(b) gravity fed.

There is mixed opinion as to which is preferable but pump feed units, providing they are well maintained, have been shown to achieve comparable performance to gravity fed units while creating considerable saving in the capital cost of installation because they require less height. Gravity fed units, on the other hand, fare better with inconsistencies in the feed rate and are less demanding in terms of wear and tear and maintenance.

No Canadian plant has yet installed a heavy media fine coal (minus 0.5 millimetres) cleaning circuit although considerable interest has been shown in such developments abroad. The various existing systems are reviewed in a recent technical paper which is enclosed in Appendix 'A' to this Report.

Figure 4-1 shows a typical flowsheet of a heavy media bath circuit and although no exact version of this circuit is at present used in a Canadian plant, the main components are fairly representative of Canadian practice.

Figure 4-2 shows a typical flowsheet of a heavy media cyclone circuit. Again, no exact version exists in a Canadian coal preparation plant, but the basic concepts employed are familiar in gravity fed circuits employed in Canadian plants. Pump fed versions involve direct passage of the deslimed raw coal into a media mixing pump box from which the feed mixture is pumped directly to the cylcone(s). The remainder of the circuit is then similar to that given in Figure 4-2.

In Figure 4-3, a more detailed indication of the magnetite medium control and recovery system employed for a heavy media circuit is shown.

4.2 MAGNETITE PREPARATION AND USAGE

In Canada, current practice for introducing magnetite is by means of water flushing or mixture of dry bulk powder in a mixing tank. Canadian plants usually store bulk magnetite in quantities of up to 6 months' supply in a designated area within the plant. It is then withdrawn as needed and washed into the dilute recovery circuits in the plant. In some cases (as for Figure 4-3) the magnetite is first densified in an independent circuit in which a wet drum magnetic separator produces an overdense concentrate which is then collected in an overdense tank. In a control system employing what is referred to as a 'rising density principle', overdense medium is added to obtain the correct operating level for mixing with the incoming raw coal. Although it is common practice in certain coal producing countries (South Africa in particular) to mill magnetite within the plant to achieve the required media characteristics, only one plant in Canada has such facilities. The Victoria Junction plant of DEVCO, which has two stages of heavy media cyclone separation, has found by experience that in order to effectively operate the primary (low density) stage at cut point densities of as low as 1.3, it is essential that the magnetite medium be as finely ground as practicable. Figure 4-4 shows a continuous milling system of the type employed in South African plants. DEVCO uses a batch milling system employing four ball mills which are used almost continuously in various combinations of pairs to produce the required medium.

4.3 LOSS CONTROL

Because sources of supply of magnetite are limited and no plant in western Canada is able to mill its medium, operations are very much at the mercy of the supplier in terms of magnetite stability and magnetic content of the bulk magnetite supply. This may be a significant factor in explaining why many Canadian plants incur exceptionally high loss of magnetite. Another reason may be that, in the case of the Rocky Mountain coals in particular, the very fine mean grain size characteristic of the raw coal creates a situation where very large amounts of near size material occur in the size range from 0.5 to 1.0 millimetres. A consequence of this, is the tendency for washed coal to pack tightly on the drain and rinse screen, thereby reducing drainage rates and causing long retention of magnetite especially during rinsing. Many operators have installed powerful water spray systems to replace shower boxes in an attempt to reduce medium carryover. Almost all operators have installed large numbers of dams or barriers across the screen flow in an attempt to disturb the bed and release more magnetite. There is little published evidence to suggest that these measures have resulted in a significant reduction in magnetite loss. It has however been suggested that much of the heavy losses occur as a result of surges in coal flow and fluctuation in water supply to the sprays. Most operators are engaged in some form of investigation into causes and remedies for magnetite loss.

In the conventional medium recovery circuit, concurrent wet drum magnetic separators containing low intensity ceramic permanent magnets are used (See Figure 4-5) to recover magnetite from dilute medium. In most plants, two stages i.e. primary and secondary, are used. The second stage performs as a scavenger, re-treating the tailings of the first usually after a thickening step involving a cylcone or conical settling tank. Several of the earlier plants have subsequently installed some form of final scavenging step either by introducing another stage wet drum separator to treat all effluent flows passing to the thickener, or by using a Magnadisc separator of the type shown in Figure 4-6 and featured in Figure 4-3.

It should be noted from the flowsheet Figure 4-3, that as a further measure of magnetite recovery, the centrates from the basket-type centrifuges are always routed into the dilute medium circuit. Also, the effluent from the secondary magnetic separator is utilized for the first rinsing stage on the drain and rinse screens, as a further conservation procedure.

The survey of magnetite users which forms part of the scheduled work for this Project is expected to provide further, more specific details of current practice and problems in magnetite usage as a coal cleaning heavy media.

TABLE 4.01

DETAILS OF CANADIAN COAL PREPARATION PLANTS
USING HEAVY MEDIA SEPARATION, (PART A)

PLANT	BYRON CREEK	ELKVIEW	FORDING RIVER	GREENHILLS	LINE CREEK		VICTORIA JUNCTION (1) CENTRAL COAL PREPARATION PLANT	
Coalfield	Crows Nest	Crows Nest	Elk Valley	Elk Valley	Elk Valley		Sydney	
Coal Rank ISO	4	4	4	4	4		7	
ASTM	mvb	mvb	mvb	mbv	mvb		mvBb	
Commissioned	1986	1970 (1972)+	1972 (1980)+	1983	1982	1983	1976	
Feed Capacity, tonnes per hour	450	1600	1200	400	270	360	690	
Plant Recovery, %	94	76	72		82	73		90
							Primary	Secondary
Clean Coal Production++ 10^6 tonnes/year, 1983	2.0 T	6.0 M	4.5 M	1.8 M	1.4 T	1.3 M	1.28 M	0.46 T
Typical % minus 0.6 mm	30	35	35	40	30	30	25	15
Typical Clean Coal Anslysis:								
% Asn	15 ± 1	9.5 ± 0.5	9.5 ± 0.5	8.0 ± 0.5	16.0 ± 1.	9.5 ± 0.5	3.0	
% Total Moisture	8.0	8.0	8.0	8.5	7.0	8.0		
% Volatile Matter	22-25	19-22	21-24	22-25	19.5-22.5	19.5-22.5	33-35	33-35
% Sulphur	0.5	0.4	0.4	0.4	0.5	0.4	1.20	2.5-3.0
FSI	-	6-8	5.7	5.7	-	5-7	7.5	-
Specific Energy, J/gm	26,750				26,800			30,000
Calorific Value (Btu/lb)	(11,500)				(11,520)		-	(12,900)
UNIT PROCESSES: SIZE RANGE OF FEED (mm)								
Heavy Medium Vessels	-	100 x 6	125 x 10	-	50 x 6*	-		-
Heavy Medium Cyclone	50 x 0.6 or 6 x 0.6	6 x 0.6	10 x 0.475	40 x 0.6	-	50 x .0.6		38 x 0.6
Water-only Cyclones	0.6 x 0.15	0.6 x 0	0.75 x 0	0.6 x 0	-	0.6 x 0		0.6 x 0
Frotn Flotaton	-	0.15 x 0	0.15 x 0	0.15 x 0		0.15 x 0		-
Fine Coal Detwatering**	RVF	RVF	Screen B.C. + RVF	RVF	Solid B.C.	Screen B.C.		Screen B.C.
Tnermal Dryer	FB 50 x 0	FB 6 x 0	FB 40 x 0	FB 40 x 0 -		FB 50 x 0		-
Fine Rejects Dewatering	Lagoon	Lagoon	Lagoon	Lagoon		***T-WP		Lagoon

Note: (1)Plant has 2 feed systems, 430 and 250 tph respectively. The larger circuit wasnes hign sulphur content (2.0-4.0%) coals at a primary cut-point of around 1.30, the smaller circuit raw coals (1.2-2.0% S) at a primary cut-point about 1.45. Botn primary products are combined on a common metallurgical product conveyor. Rejects from botn circuits are rewashed in a middlings circuit at about 1.60 sp.gr. to produce tne tnermal coal quality.

* Untreated small coal blended with cleaned coarse coal.

** B.C. - Bowl Centrifuge, R.V.F. - Rotary Vacuum Disc Filter

*** T-WBP - Twin-wire Belt Presses

+ Major extension

++ M = Metallurgical, T = Thermal

FB= Fluid Bed Dryer

TABLE 4.01 (CONT'D)

DETAILS OF CANADIAN COAL PREPARATION PLANTS
USING HEAVY MEDIA SEPARATION, (PART A)

PLANT	CARDINAL RIVER	COAL VALLEY	GREGG RIVER	SMOKY RIVER	BULLMOOSE	QUINTETTE
Coalfield	Cadomin-Luscar	Coalspur	Cadomin-Luscar	Smoky River	Peace River	
Coal Rank ISO	4	8	4	3	4	
ASTM	mvb	hvCb	mvb	lvb	mvb	
Commissioned	1970 (1979)+	1978	1983	1969	1983	1983
Feed Capacity, tonnes per hour	600	720	600	590	450	1200
Plant Recovery, %	80	56	75	72		
Clean Coal Production++ (10^6 tonnes/year, 1983)	3.0 M	3.2 T	2.1 M T	1.7 M	1.7 M 0.3 T	5.0 M
Typical % minus 0.6 mm	28	25	30	40	30	35
Typical Clean Coal Analysis:						
% Ash	9.25 ± 0.5	10.0	9.5 ± 0.5	7.5	9.5	9.5
% Total Moisture	7.0	8.5	8.0	6.0	8.0	8.0
% Volatile Matter	21 - 24	33 - 35	22 - 25	17.5 - 20.0	22 - 23	22 - 23
% Sulphur	0.37	0.3	0.3	0.5	0.3	0.3
FSI	5 - 7	-	5 - 8	-	6 - 7	6 - 7
Specific Energy, J/gm	-	25,120		-	-	-
Calorific Value (Btu/lb)		(10,800)		-	-	-
Unit Processes: Size Range of Feed (mm)						
Heavy Medium Vessel	-	100 x 13	75 x 10	-	-	150 x 8
Heavy Medium Cyclone	45 x 0.6	13 x 0.6	10 x 0.6	38 x 0.6	38 x 0.6	8 x 0.6
Water-only Cyclone	0.6 x 0	0.6 x 0.15*	0.6 x 0	-	0.6 x 0	0.6 x 0
Froth Flotation	0.15 x 0	-	0.2 x 0	0.6 x 0	0.15 x 0	0.15 x 0
Fine Coal Detwatering**	Screen B.C. + R.V.F.	Screen B.C.	R.V.F.	R.V.F. FB 38 x 0	R.V.F. FB 38 x 0	Screen B.C. FB 50 x 0
Thermal Dryer	FB 45 x 0	FB 50 x 0.15	FB 45 x 0	Screen B.C.	Lagoon	Lagoon
Fine Rejects Dewatering	Solid B.C. + Lagoon	T-WBP***	Solid B.C.	+H-F Dryer		

* High ash fines rejected by classification
** B.C. - Bowl Centrifuge, R.V.F. - Rotary Vacuum Disc Filter
*** T-WBP - Twin-wire Belt Presses, commissioned 1981
+ Major extension
++ M = Metallurgical, T = Thermal

H-F Dryer - Holo-Flyte Dryer (Commissioned 1978)
FB = Fluid Bed Dryer

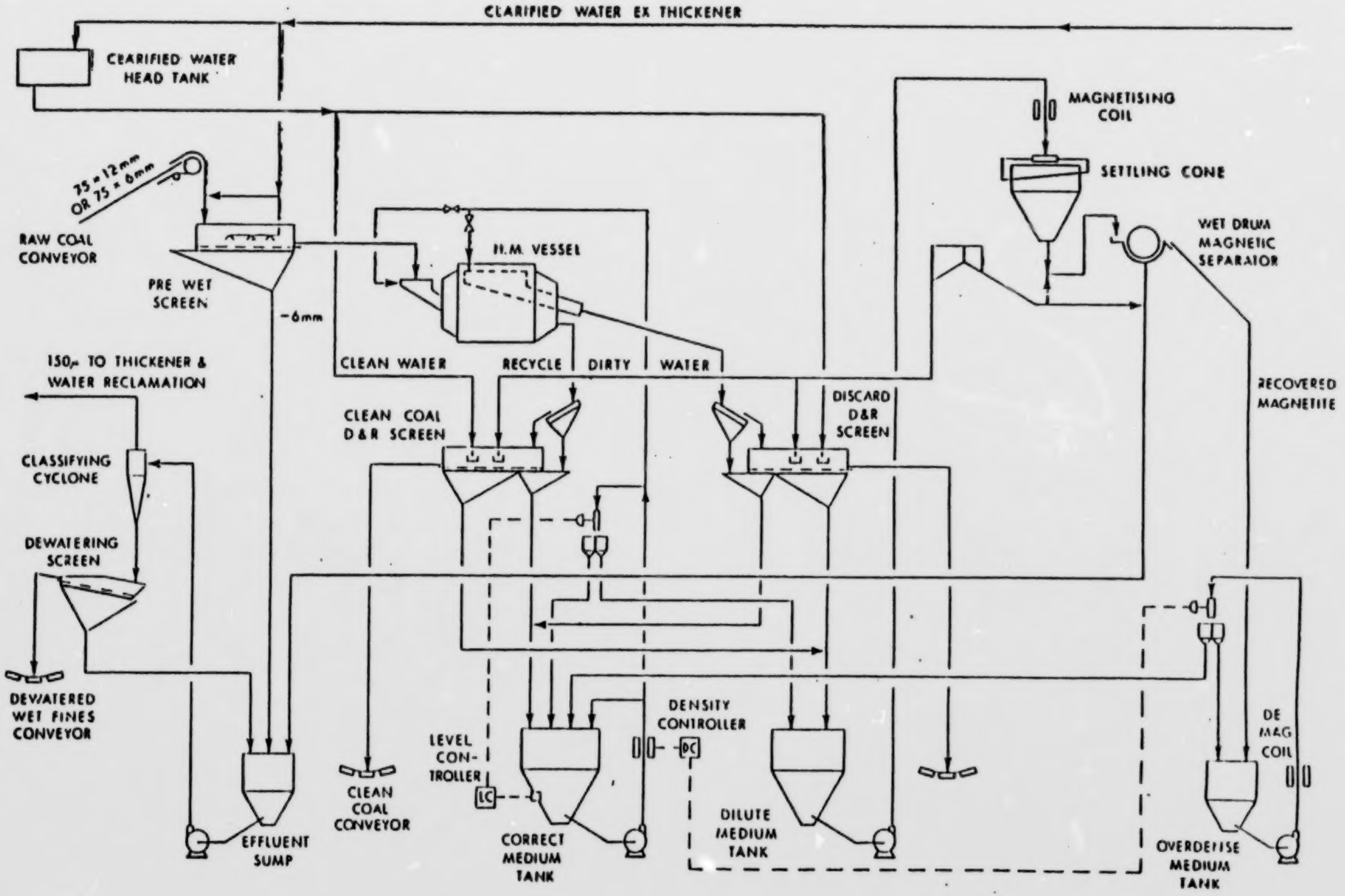
CLARIFIED WATER EX THICKENER
CLARIFIED WATER HEAD TANK
MAGNETISING COIL
SETTLING CONE
WET DRUM MAGNETIC SEPARATOR
75 x 12mm OR 75 x 6mm
RAW COAL CONVEYOR
PRE WET SCREEN
H.M. VESSEL
-6mm
150µ TO THICKENER & WATER RECLAMATION
CLEAN WATER
RECYCLE
DIRTY
WATER
RECOVERED MAGNETITE
CLEAN COAL D&R SCREEN
DISCARD D&R SCREEN
CLASSIFYING CYCLONE
DEWATERING SCREEN
DEWATERED WET FINES CONVEYOR
DENSITY CONTROLLER
DC
DE MAG COIL
LEVEL CON-TROLLER
LC
CLEAN COAL CONVEYOR
EFFLUENT SUMP
CORRECT MEDIUM TANK
DILUTE MEDIUM TANK
OVERDENSE MEDIUM TANK

FIGURE 4-1: TYPICAL FLOWSHEET OF A HEAVY MEDIA VESSEL CIRCUIT

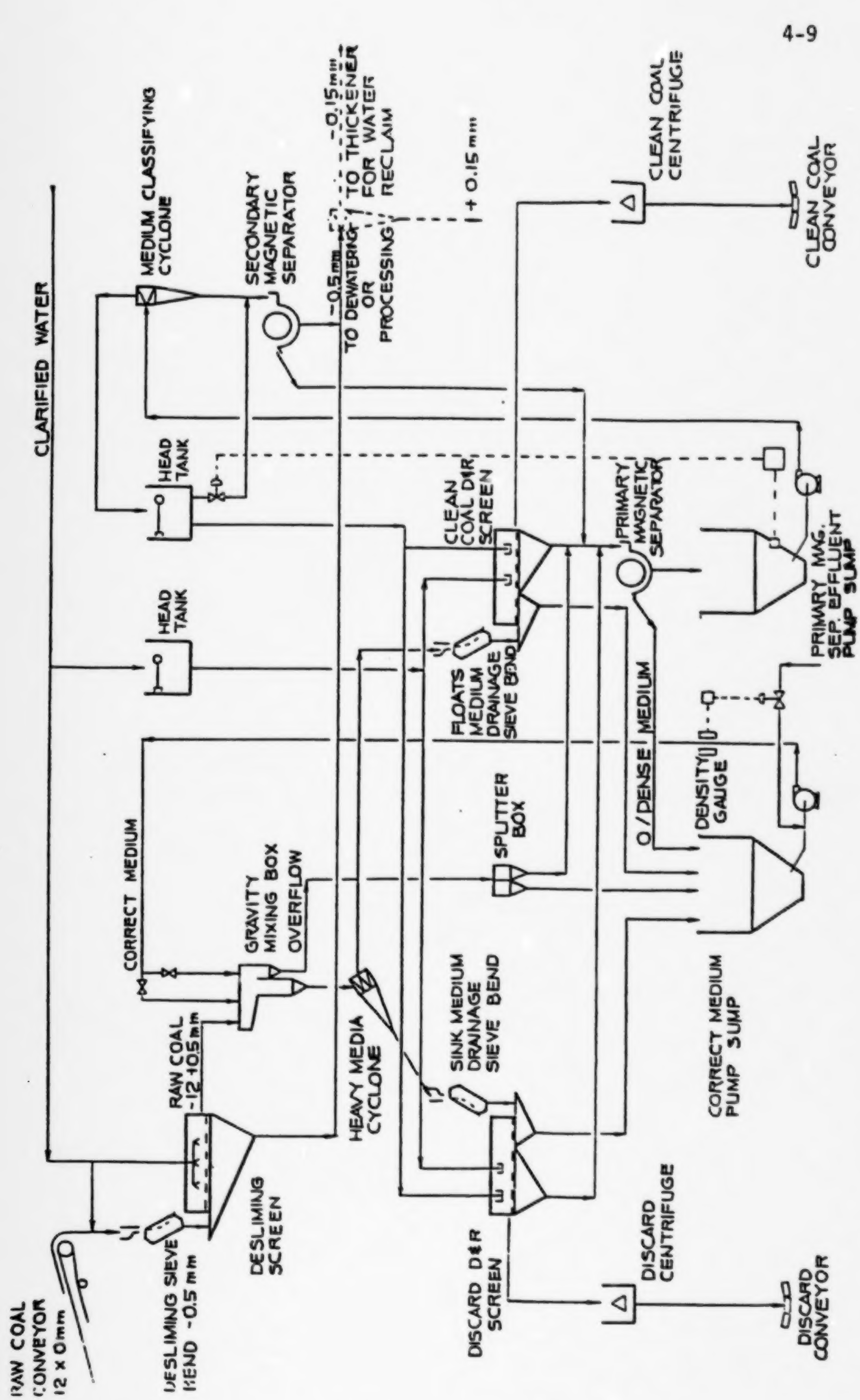
RAW COAL CONVEYOR 12 x 0mm
DESLIMING SIEVE BEND -0.5 mm
DESLIMING SCREEN
RAW COAL -12 x 0.5mm
CLARIFIED WATER
CORRECT MEDIUM
GRAVITY MIXING BOX
OVERFLOW
HEAVY MEDIA CYCLONE
SINK MEDIUM DRAINAGE SIEVE BEND
DISCARD D&R SCREEN
DISCARD CENTRIFUGE
DISCARD CONVEYOR
CORRECT MEDIUM PUMP SUMP
SPLITTER BOX
O/DENSE MEDIUM
DENSITY GAUGE
FLOATS MEDIUM DRAINAGE SIEVE BEND
HEAD TANK
HEAD TANK
CLEAN COAL D&R SCREEN
PRIMARY MAGNETIC SEPARATOR
PRIMARY MAG. SEP. EFFLUENT PUMP SUMP
MEDIUM CLASSIFYING CYCLONE
SECONDARY MAGNETIC SEPARATOR
-0.5mm TO DEWATERING OR PROCESSING
-0.15mm TO THICKENER FOR WATER RECLAIM
+0.15mm
CLEAN COAL CENTRIFUGE
CLEAN COAL CONVEYOR

FIGURE 4-2: TYPICAL FLOWSHEET OF A HEAVY MEDIA CYCLONE CIRCUIT

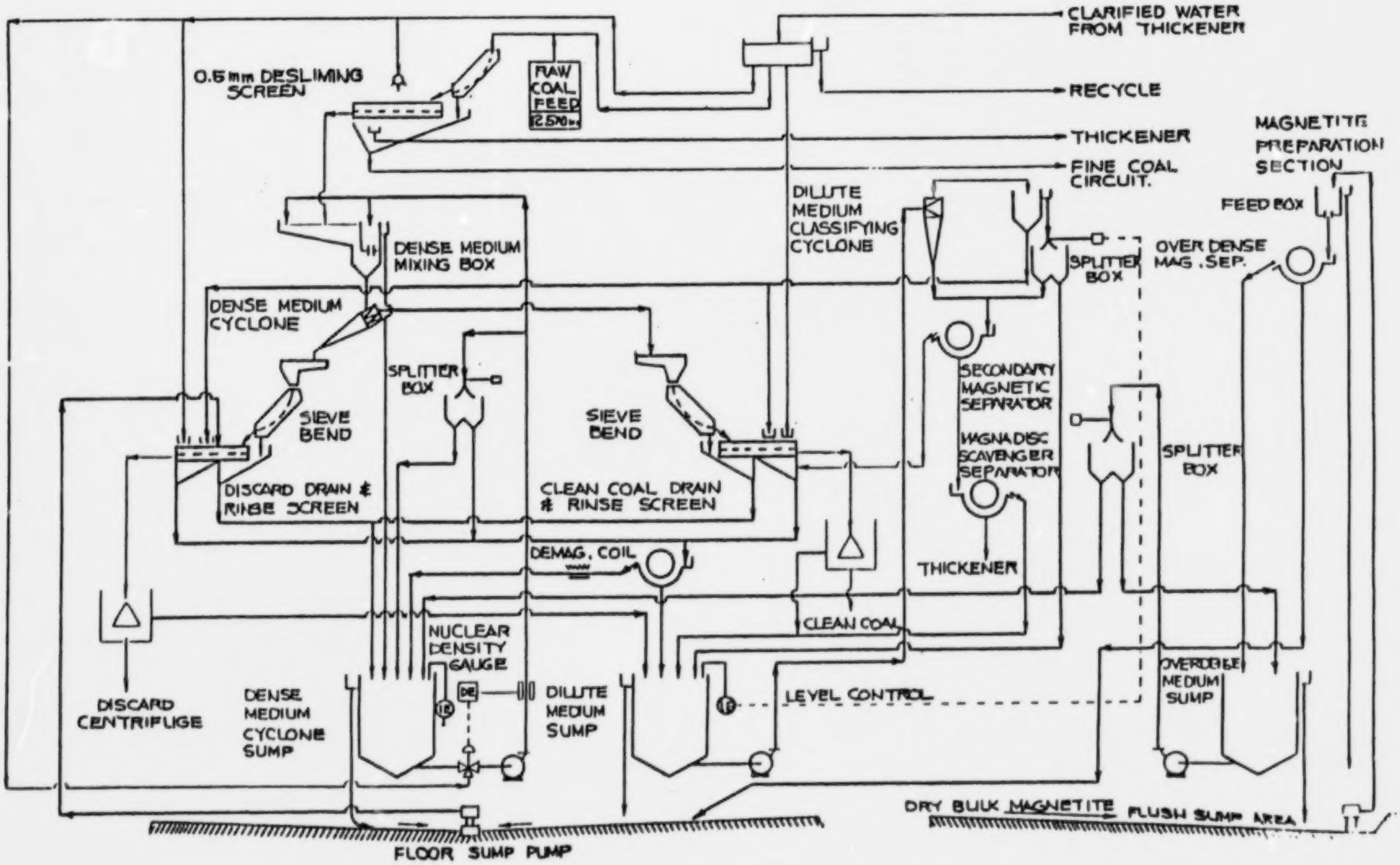
CLARIFIED WATER FROM THICKENER
RECYCLE
THICKENER
FINE COAL CIRCUIT.
MAGNETITE PREPARATION SECTION
FEED BOX
OVER DENSE MAG. SEP.
0.5mm DESLIMING SCREEN
RAW COAL FEED
12.5x0mm
DILUTE MEDIUM CLASSIFYING CYCLONE
DENSE MEDIUM MIXING BOX
DENSE MEDIUM CYCLONE
SPLITTER BOX
SIEVE BEND
SIEVE BEND
SPLITTER BOX
SECONDARY MAGNETIC SEPARATOR
MAGNADISC SCAVENGER SEPARATOR
SPLITTER BOX
DISCARD DRAIN & RINSE SCREEN
CLEAN COAL DRAIN & RINSE SCREEN
DEMAG. COIL
THICKENER
CLEAN COAL
NUCLEAR DENSITY GAUGE
DE
DISCARD CENTRIFUGE
DENSE MEDIUM CYCLONE SUMP
DILUTE MEDIUM SUMP
LEVEL CONTROL
OVERDENSE MEDIUM SUMP
DRY BULK MAGNETITE
FLUSH SUMP AREA
FLOOR SUMP PUMP

FIGURE 4-3: MAGNETITE MEDIUM CONTROL AND RECOVERY SYSTEM

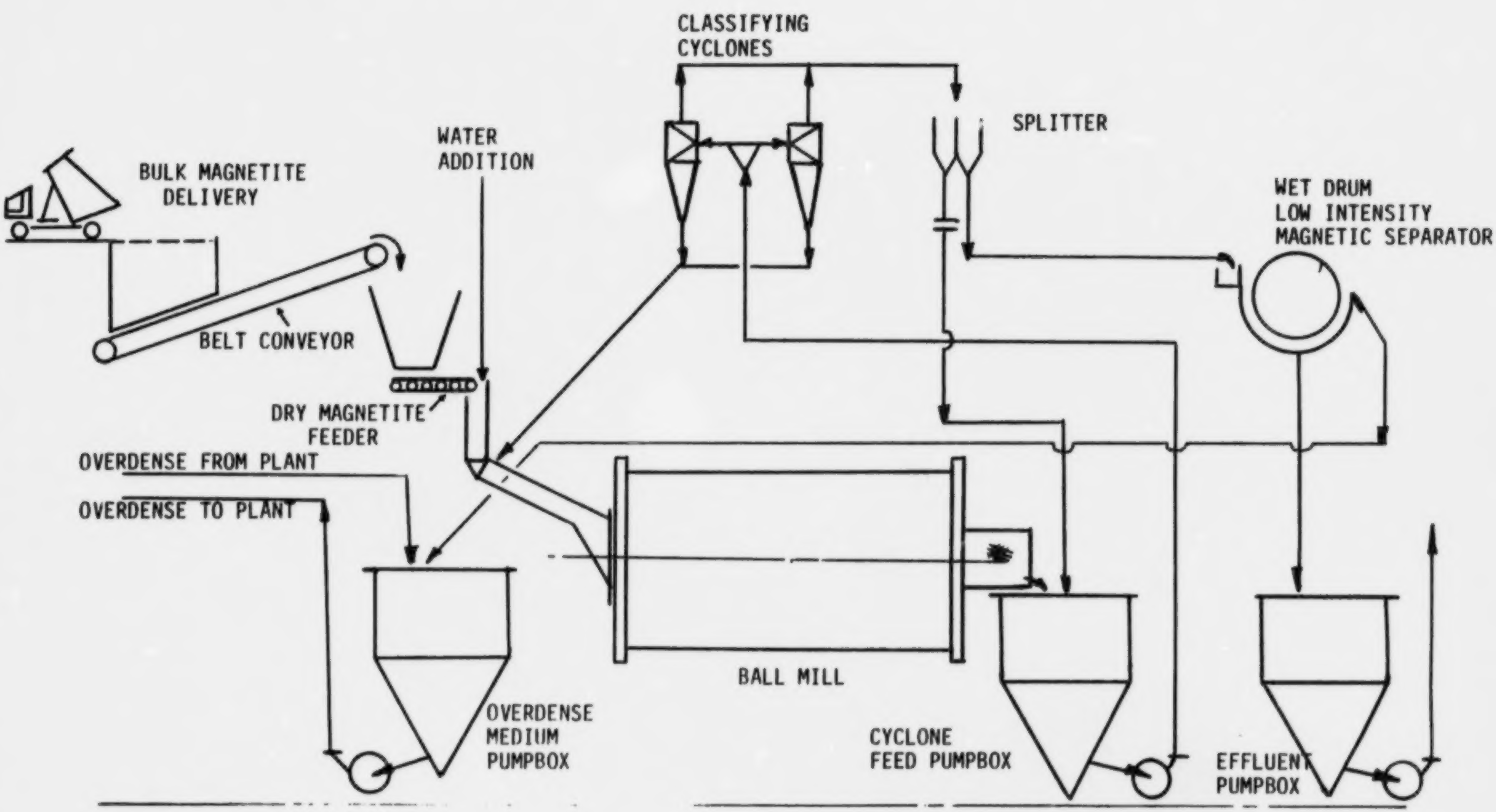
CLASSIFYING
CYCLONES
SPLITTER
WATER
ADDITION
BULK MAGNETITE
DELIVERY
WET DRUM
LOW INTENSITY
MAGNETIC SEPARATOR
BELT CONVEYOR
DRY MAGNETITE
FEEDER
OVERDENSE FROM PLANT
OVERDENSE TO PLANT
BALL MILL
OVERDENSE
MEDIUM
PUMPBOX
CYCLONE
FEED PUMPBOX
EFFLUENT
PUMPBOX

FIGURE 4-4: IN-PLANT MAGNETITE MILLING AND CLASSIFICATION CIRCUIT

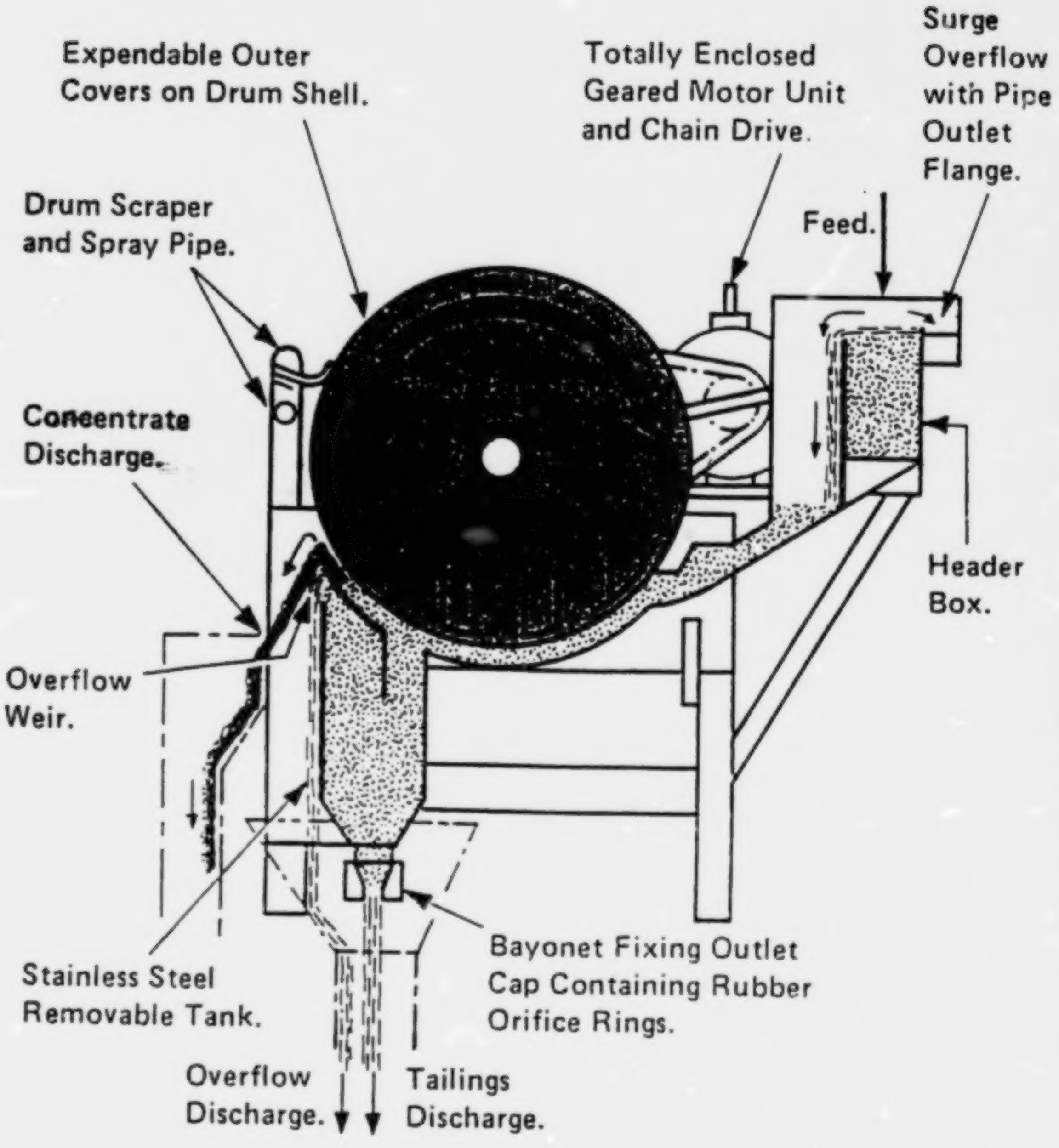
Expendable Outer Covers on Drum Shell.
Totally Enclosed Geared Motor Unit and Chain Drive.
Surge Overflow with Pipe Outlet Flange.
Drum Scraper and Spray Pipe.
Feed.
Concentrate Discharge.
Header Box.
Overflow Weir.
Bayonet Fixing Outlet Cap Containing Rubber Orifice Rings.
Stainless Steel Removable Tank.
Overflow Discharge.
Tailings Discharge.

FIGURE 4-5: LOW INTENSITY WET DRUM MAGNETIC SEPARATOR

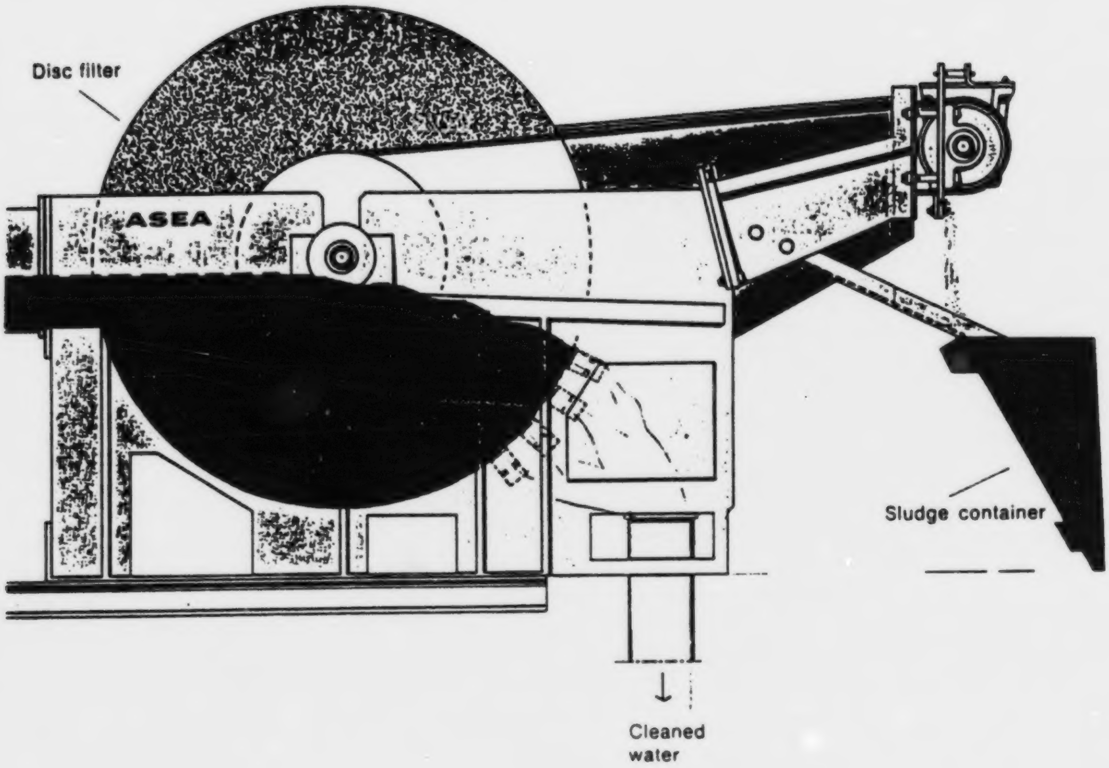
Disc filter
ASEA
Sludge container
Cleaned water

FIGURE 4-6: MAGNADISC LOW INTENSITY DISC MAGNETIC SEPARATOR

REFERENCES - SECTION 4.0

Anon.	'Dense Medium Coal Preparation.' Simonacco Limited (U.K.) Publication, 1962.
D. N. Collins, et al	'Separation Efficiency in Dense Media Cyclones.' Trans. Inst. Min. Metall., Section C, V92, pp. C38-C51, March 1983.
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D. R. Kelland	'Heavy Medium Recovery in Coal Washing by Continuous High Gradient Magnetic Separation.'
C. Krijgsman	'The Dutch State Mines Dense Medium Cyclone Washer.' Colliery Eng. V37, pp. 328-332 and pp. 383-386, 1960.
G. D. Sealy and W. F. Howell	'Magnetic Recovery of Magnetite and Ferrosilicon from Heavy Media Circuits.' SME, AIME Meeting (source uncertain).
A. Wright	'Magnetite Recovery Systems for Heavy Media Cleaning Circuits.' Coal Age, pp. 58-61, July, 1984.

5.0 PHYSICAL AND RHEOLOGICAL PROPERTIES AND TEST EQUIPMENT

5.0 PHYSICAL AND RHEOLOGICAL PROPERTIES AND TEST EQUIPMENT

5.1 MINERALOGICAL PROPERTIES OF MAGNETITE

Magnetite is a naturally occurring mineral of cubic crystal structure. It belongs to the spinel family, having the chemical formula $Fe^{2+}Fe_2^{3+}O_4$. The chemical structure is based on a close packed cubic oxygen lattice. The oxygen ions (1.32A) are larger than the Fe^{2+} (.80A) and the Fe^{3+} (.67A) and consequently the Fe^{2+} and Fe^{3+} fit into the holes (or sites) within the oxygen lattice. Each 'molecule' of Fe_3O_4 has eight tetrahedral and four octahedral sites, the positions of which can be seen in Figure 5-1. One of the Fe^{3+} ions occupies an octahedral site and the other Fe^{3+} a tetrahedral site while the Fe^{2+} ion occupies another another octahedral site. This leaves two of the octahedral sites and seven of the tetrahedral sites unoccupied. Many cations (Ti^{4+}, Mg^{2+}, and Mn^{2+}, etc) are of similar size to the iron cations, and it is common to find natural substitution of the iron yielding magnetite with inferior magnetic properties.

5.2 SPECIFICATIONS FOR USAGE AS A MAGNETITE MEDIUM

The specifications for magnetite as generally agreed upon by consumers and producers throughout the world are as follows:

Particle-size distribution	Maximum 5% by weight larger than 45 micron and 30% by weight smaller than 10 micron
Relative density	4.9 to 5.2 g/cm³
Magnetic content	Not less than 95% by weight

It should be noted that these specifications are based on those originally set by the British coal-mining industry. As such, they may not be strictly applicable to all other conditions, and they may also have to be related to plant practice. These specifications do not include any reference to rheological properties, such as viscosity and settling rates at specific slurry densities, which are important in plant performance and separation, and standard values relating to plant performance must be established by the operator.

5.3 DETERMINATION OF PHYSICAL AND RHEOLOGICAL PROPERTIES OF MAGNETITE

5.3.1 Physical Properties

Several recognized procedures and equipment are used in the determination of the various properties of magnetite. These are summarized in Table 5.01.

TABLE 5.01

METHODS USED IN THE DETERMINATION OF THE PHYSICAL PROPERTIES OF MAGNETITE

Property	Method or Equipment	Limitations
Particle size	Dry screening	Valid only above 53 micron.
	Wet screening	Many variables introduced.
	Cyclosizer	Time-consuming; only limited points obtained.
	Coulter method	Sensitive to auto coagulating properties.
	Sedigraph or other sedimentation analyzer	High density of particles causes rapid settling.
	Bahco or Haultain: Pneumatic classification	Time consuming, potential high loss of very fine material.
	Microtrac of other microscopic methods	Irregular shapes may introduce bias.
	Optical sizing	Sophisticated equipment needed.
Magnetic content	Davis tube	Many variables.
	ISO Apparatus	Simple method with good reproducibility.
	Magnetic chute	Variable magnetic field.
	Hand magnet	Accuracy depends on operator. Only approx.
Density	Beckman pycnometer	Slightly operator-dependent.
	Density bottle	Often difficult with fine powders.

A comparison produced by Mintek of South Africa of the size analytical data obtained by means of the various size analyzing equipment is shown in Figure 5-2.

5.3.2 Rheological Properties

These include viscosity; stability; ease of demagnetization; and magnetic susceptibility. Equipment most commonly used in testing these properties in coal industry usage is listed in Table 5.02.

TABLE 5.02

METHOD USED IN THE DETERMINATION OF THE RHEOLOGICAL PROPERTY OF MAGNETITE

Property	Method of Equipment	Limitations
Viscosity	Stormer viscometer	Reliability only achieved by custom modification. Demagnetization essential.
	DeVaney-Shelton consistometer	Unreliable unless magnetite is totally demagnetized.
Stability	F5 Index Tube	Operator influence very significant.
	DRL 'U' tube - apparatus	Not developed to commercial usage.
	Settling Tests	No standardized method available.
Magnetic Susceptibility/ Coercive Force*	Satmagan balance	Limited reliability.
	Magnetometer*	Used by ACIRL.
	Thermogravimetric	Measures hysteresis curve only and requires calibration.
	Eaton apparatus	Reference is $Hg\ Co\ (SCN)_4$. which must be carefully prepared.
Demagnetization	Simon-Carves method	Operator influence, but reproducibility is reasonable.

5.3.3 Chemical Analysis

Chemical analysis, particularly for iron content, is often used for distinguishing magnetites for different sources. Two forms of analysis are common:

(a) Determination of total iron content which is determined using the volumetric method described in ISO 2597 (Method 1b);

(b) Determination of ferrous iron content which is determined by dissolving the sample in hydrochloric acid in an atmosphere of nitrogen and titrating ferrous iron from the resultant solution using potassium dichromate.

More detailed chemical analysis may be obtained by instrumental methods such as Inductively Coupled Plasma (ICP), to determine the following:

- SiO_2, Al_2O_3, TiO_2, P, S, Ba, Cd, Zn, Ca, Mg, Ni, Co, Cu, Au and Ag.

Normally, an analysis of this type would not be necessary for known sources and this type of examination would be carried out for potential new sources of media, including fly ash derived material.

5.3.4 Equipment Details and Methodology

(a) Sieving Methods

Dry Screening:

For dry screening, use is made of standard sieves with apertures of 53, 45, and 38 micron respectively. These sieves are placed in descending order of fineness with a catchment basin at the bottom to form a nest of sieves, and 20 grams of magnetite as received is placed on the top screen (53 micron aperture). A lid is then placed on the arrangement, and the whole nest of sieves is shaken in an automatic sieve shaker for 10 minutes. This time limit was arrived at by use of a method described by Gaudin for the determination of sieving end-point. The oversize remaining on each sieve is then carefully collected and weighed, the percentage being calculated on the basis on the total mass used.

Wet Screening:

Wet screening is done with the same standard sieves used for dry screening, but included, in addition, is a sieve of 25 micron aperture. However, in contrast to the dry-screening method, only one sieve can be used at a time. A special apparatus designed at Mintek in South Africa is shown in Figure 5-3. This apparatus comprises a high frequency vibrating feeder stripped of the feed chute. Bolted to the vibration unit is a steel plate with a rod and an adjustable ring into which the standard sieves can fit. The variable-speed control is set to mid-range, and is kept there with no adjustment to ensure that the sieve is always vibrated at a fixed amplitude and frequency.

In the determination of the particle-size distribution curve, a 20 gram sample of magnetite as received is accurately weighed into a deep basin and wetted by the careful addition of water. The sieve with the smallest aperture (25 micron) is placed in the ring and clamped tight. A 25 litre bucket is placed underneath the sieve, and the vibrator switched on. The flowrate of the wash water is set at approximately 0.5 litre per minute by use of a rotameter and then the wetted sample is carefully washed onto the sieve, so that no material splashes over the side of the sieve.

Once all the material has been introduced onto the sieve, the wash water is used to wash the sample on the continuously vibrating sieve for 10 minutes. The flow of water and the vibrator are then switches off, and the screen removed. The oversize material is carefully washed off into a deep basin so that no material is lost, and the undersize in the bucket is filtered, dried, and weighed. This process is repeated, oversize material and the sieve with the next largest aperture (38 micron) being used. This is done until all the sieves have been used and the various fractions have been dried and weighed. The percentages are calculated on the basis of the total mass of the sample. A curve is then constructed of the cumulative passing percentage of material versus the sieve aperture. In the determination of the fraction that would be obtained by screening for material smaller than 10 micron, a Fritsch Analysette sieving apparatus and accompanying microsieve of 10 micron aperture can be used. The suspending medium employed is usually alcohol because it has a lower surface tension than water. After 5 grams of the magnetite smaller than 25 micron, obtained by wet screening, has been spread on the microsieve, it is placed in the apparatus. Enough alcohol must then be added to cover the sieve, before this cover is placed on the sieve. The vibrator is then switched on and allowed to operate for 20 minutes. The oversize remaining on the sieve is washed into a container, dried, and weighed, and the undersize is calculated by difference. A calculation can then be carried out to relate the percentage of material smaller than 10 micron to the mass of the total sample.

An alternative method using a microsieve and an ultrasonic bath, as suggested by Finch and Leroux, may be used instead of the Fritsch Analysette apparatus.

(b) Elutriation Size Analyzers

Warman Cyclosizer:

The five cyclones which form the basis of the Cyclosizer are arranged in series such that the overflow of one unit is the feed for the next in line (See Figure 5-4). The individual units are in the 'upside-down' position with reference to conventional arrangements and at the apex of each a chamber is situated so that the apex discharge is effectively closed. Water is pumped through the five units at a specified rate (as indicated on a rotameter) and a sample of solids is introduced from a separate container into the stream ahead of the cyclones. The introduction of the sample is spread over five minutes.

In passing through the Cyclosizer, the solids are distributed to the five cyclones in accordance with their Stokesian sizing. The initial distribution is only approximate with each apex chamber containing an excess of undersize material. With continued flow of water after the initial distribution, particles smaller than a 'limiting size' for each cyclone are gradually elutriated to the overflow. Each cyclone is thus analogous to a sieve in which the aperture is dependent on flowrate and the Stokes' Law variables, i.e. the liquid viscosity and the specific gravity differential between solid and liquid. Typical values of the limiting sizes for each cyclone are shown on the Table 5.03.

The precision of separation improves with increase in elutriation time, but 10 minutes' elutriation is often quite adequate and it is rarely necessary to exceed 30 minutes. When the allotted elutriation time has elapsed, the sized fractions are collected by discharging the contents of each apex chamber into separate beakers. The solids are settled, decanted (or filtered) and dried and weighed to determine the size distribution. Solids passing the No. 5 cyclone are determined by difference.

The following example, outlines the general procedure but, depending on the ultimate purpose of the analysis, a more or less detailed approach may be desired.

1. Weigh out sample, slurry with water and transfer to the sample container.
2. Fit sample container on panel, start pump and pass water through the Cyclosizer to expel air.
3. Set water flow at 25 percent greater than the pre-determined separation flowrate, open port on sample container and obtain a preliminary distribution of solids to the cyclones (five minutes).
4. Reduce flowrate to the pre-determined value and elutriate for 10 to 30 minutes, depending on precision required.
5. When elutriation is complete, increase the flowrate and discharge the solids of each apex chamber in turn through the apex valve. Collect the discharged solids in separate beakers.
6. Filter, dry and weigh each fraction and calculate solids passing No. 5 cyclone by difference.

TABLE 5.03
LIMITING PARTICLE SIZES IN THE CYCLOSIZER

Typical values of the limiting particle sizes for each cyclone at different levels of particle specific gravity

Cyclone No.	Equivalent Stokesian Diam. (Microns) S.G. = 2.7 (Quartz)	S.G. = 5.2 (Pyrite)	S.G. = 7.5 (Galena)
1	44	27	22
2	35	22	18
3	23	14	11
4	15	9	8
5	9	6	5

This method of size distribution analysis is the preferred method of the Australian coal industry.

(c) Sedimentometer Size Analyzers

Sedigraph:

Sedigraph by Micromeritics is a well-known commercially available instrument based upon the gravitational x-ray particle size analysis. This instrument automatically presents cumulative percentage frequency and the sedimentation tank is driven in such a way that the concentration is recorded directly as a function of the Stokes' diameter. X-rays from a 22.6 keV source are collimated into a narrow beam and pass through a 3.6 millimetre thickness suspension. The sedimentation tank (35 millimetres high) is filled and emptied with suspension with a built-in pump. The transmitted radiation is detected as pulses by a xenon filled scintillation detector. The counting electronics gives a voltage powder concentration. An operational schematic of the Sedigraph is shown in Figure 5-5.

The range of application is 1-50 micron for most materials including magnetite.

WASP Size Analyzer (Ladal Wide Angle Scanning Photo-sedimentometer):

The instrument is based on concentration measurements of a suspension settling under gravity. Particle size is calculated using Stokes' equation and the changing concentration with time and height of fall is monitored by the changing attenuation of a beam of white light. A scanning system may be activated to give very short analytical times.

The attenuation is related to the projected area of the particles in the light beam by the Beer-Lambert Law. The light interrupted by the particles consists of two parts, that incident on the particles and the diffracted light. The latter part is picked up by the wide angle receiver to provide a constant value for extinction coefficient. The recorded distribution is therefore by surface and this can be integrated to give a weight distribution.

Since the attenuation is proportional to surface, the specific surface of a powder may be rapidly determined. Furthermore, the degree of dispersion of the powder in suspension may be monitored and the effectiveness of various dispersing agents determined. In the case of magnetite, the test powder must be fully demagnetized prior to testing. This is achieved by heating the powder to above 600°C (Curie temperature).

The two parallel beams of white light of circular cross-section are produced from a common light source. One passes through the measurement arm of the instrument and the other passes through a reference arm. The measurement beam passes through a sedimentation tank on to a photocell and the reference beam passes through a variable aperture on to a second photocell coupled in opposition to the measurement photocell. (See Figure 5-6).

During an analysis the sedimentation tank remains stationary and the optical assembly scans to the surface of the suspension. Scanning is activated after a delay time of 4 minutes at an initial depth of 18 cm which is scanned in 18 minutes. The return scan is completed in less than 5 minutes, making a total analysis time of less than half an hour.

Two alternatives are available for data presentation:

EITHER:

1. A pen recorder for simple recording of attentuation with time; the readings may be readily converted into particle size distribution by surface, by a simple numerical calculation and this can be graphically integrated to give the weight distribution.

OR

2. A direct plotting facility which comprises an X-Y plotter and a special data recording unit; this permits direct plotting of the % undersize by surface against Stokes' diameter.

The weight specific surface (S_w) of a powder in an agitated suspension is given by the equation:

$$S_w = 6.14\left(\frac{D_o}{C}\right)$$

where D_o is the optical density and C is the concentration by weight of powders in suspension. The surface-volume mean diameter (d_{sv}) is given by:

$$d_{sv} = \frac{0.977}{\rho}\left(\frac{C}{D_o}\right)$$

where ρ is the powder density.

If, in an agitated suspension, d_{sv} increases with time flocculation is occurring. If d_{sv} decreases flocs are breaking up or the powder is dissolving.

The cumulative percentage undersize by surface (F_2) of a sedimenting suspension is directly related to the optical density at time t since the extinction coefficient is constant.

$$F_2 = 100 \left(\frac{D_t}{D_o}\right)$$

The cumulative percentage undersize by weight (F_3) is given by:

$$F_3 = \sum^{t} \Delta\, Dt\ d_{st} \;/\; \sum_{t\,=\,o}^{t\,=\,max} \Delta\, Dt\ d_{st}$$

Where d_{st} is the Stokes' diameter.

Advantages:

- Short measurement times due to the scanning facility;
- Undisturbed sedimentation due to the stationary sedimentation tank;

- Direct reading of surface distribution, usually more meaningful than a weight distribution;
- Easy operation;
- Direct plotting facility;
- Wide size range of 2 micron to 100 micron.

(d) Microscopic Size Analytical Techniques

Optical Microscopy:

Though optical microscopy is used for the examination of particles in the range of 150 - 1 micron, its limitation is small depth of focus, which is 10 micron at 100X and about 0.5 microm at 1000X. An acceptable procedure consists of placing a small well-dispersed representative sample of the magnetite powder on a slide and measuring diameters of particles using a calibrated fibre micrometer eyepiece. This type of eyepiece has a scale and a moving hairline situated in the focal plane of the eyepiece. The hairline is moved across the scale with a micrometer spindle so that the relative position of the hairline can be accurately determined for the scale divisions on the spindle. To measure a particle diameter, the hairline is moved until it coincides with one side of the particle, and the reading on the spindle is noted. The hairline is then moved across the particle to its remotest edge, and the reading on the micrometer spindle is again noted. The difference between the wo spindle readings is an indication of the diameter of the particle. For illustration a Leitz microscope is shown in Figure 5-7.

The most difficult problem facing the microscopist is the preparation of a slide containing a uniformly dispersed, representative sample of the powder. Many methods have been suggested, but the final result often depends on the operator's skill. An acceptable procedure is to place the sample in a 10 millilitre beaker and add 2-3 millilitre solution containing 20 percent colloidon in butyl acetate, stir vigorously, and a drop of it is placed on the still surface of distilled water in a large beaker. The film resulting from the spreading of this drop is dipped up onto a clean glass microscope slide and completely dried. A dispersant may be useful for difficult powders, and of course magnetite powder must be fully demagnetized by heating to above its Curie temperature of 575°C.

To reduce the tedium of manual methods, semi-automatic aids to counting and sizing have been developed. The advantage of these aids over automatic microscopy is that human judgement is retained and cost is low. Operators can select or reject particles, separate aggregates and discriminate over choice of fields. Many such aids have been developed and these differ widely in degree of sophistication, cost, ease, mode and speed of operation. The Zeiuss-Endter particle size analyzer, the Chatfield particle size comparator, and Lark particle counter, are some of the examples of the semi-automatic microscopic devices.

The need to count and size a large number of samples has stimulated the development of automatic miscroscopes. In these instruments, the particles are passed through a light beam which then tails on a photocell. Changes in the intensity of the light beam due to the presence of particles are monitored and recorded. The Rank Cintel instrument, Mullard film scanning particle analyzer and Casella counter are some of the available instruments.

On the other spectrum are quantitative image analyzers that accept samples in a variety of forms: photographs, electron micrographs, and direct viewing. The particles are scanned by a television camera and displayed on a console and electrical information describing the sample is passed to a detector. Parameters measured include particle count, size distribution by area or some statistical diameter, projected length and intersect count and chord-size distribution. A large number of basically similar instruments have been developed including Ameda, Leitz Classimate, Millipore II MC, Bausch and Lomb quantitative metallurgical systems and Quantimet image analyzing computers. The latest version of Quantimet 720 employs a digitally controlled scan which divides the field of view into 650,000 picture points and allows the use of more sophisticated logic.

Access to such a machine for magnetite size analysis would be desirable although not necessarily preferable. At Mintek in South Africa, a Leitz-TAS image analyzer is used and the method chosen was direct measurement of an area-size distribution graph. This is done by the measurement, in a given area, of all the particles of a certain size. The size of the particle is determined by the size of the largest hexagon that can be inscribed on the particle, and then is comparable with screening. Once all the particles in a certain size have been counted, the hexagon of the next smaller size is used until all the particles in the area have been accounted for. A graph is then constructed of the size distribution of the particles.

Microtrac Size Analyzer:

Microtrac by Leeds and Northrup (68-70) is one of the highly successful instruments using the low angle forward scattering optical system. This device covers a range of 2 to 176 micron with a size distribution histogram of 13 points in about 2 to 3 minutes. The size distribution is determined by flowing particles through a sample cell which is illuminated by a continuous laser beam. The suspended particles scatter the light which is collected by a series of lenses and a rotary optical filter. The Fraunhofer plane diffraction pattern for the particles is interpreted with the aid of the specially designed optical filter and a digital microprocessor to yield a complete size distribution information. Particle concentrations must be sufficiently high to obtain a good counting statistics but sufficiently low to avoid multiple scattering, which improves accuracy. A schematic diagram of the Microtrac is given in Figure 5-8.

As there is a demagnetizing coil in the circuit through which the suspension is passed, the magnetite can be fully demagnetized prior to the analysis.

(e) Coulter Counter and Other Size Analysis Methods

Several other methods of size analysis have been reported as being used for determining the size distributions of magnetite samples. One of them, the Coulter Counter, is a method widely employed in coal and mineral size analysis, but with magnetite, there is the likelihood that auto-coagulation will be induced during the analysis causing erroneous data to be obtained. Figure 5-9 shows the principle of the Coulter Counter. For this reason, several researchers have changed to sedimentation, elutriation of centrifugal classification methods.

Another instrument, recently introduced, which is finding increasing application in coal research is the laser-based Malvern 3600 instrument, but no reference to its use with magnetite has been found.

(f) Density Measurement

Beckman Pyconometer:

This apparatus works on the principle that a sample displaces a volume of air equal to its own volume. Two cylinders of identical volume are used, one as a reference and the other for the measurement, each having a movable piston.

While both pistons are fully withdrawn, a weighed amount of sample is introduced into the sample cup and placed in the measuring cylinder. Each instrument has a specific calibrating number and the measuring piston is advanced until this number is read on the meter. The sample cup is then locked in place to give an air-tight seal, and the two cylinders are isolated from each other. The two pistons are then advanced in such a way that the pointer remains on the scale until the reference piston is in the foremost position and comes to a stop. The measuring piston is advanced until the pointer is in the centre of the scale and the valve isolating the cylinders from each other is opened. The value on the meter is then read, being the volume of the sample in cubic centimetres. The relative density of the sample can then be calculated from the formula:

Density = mass/volume

which will give the density in grams per cubic centimetre.

Density Bottle:

A standard method for determining relative density by using a 50 ml capacity density bottle is usually employed. The volume of distilled water displaced by a 20 gram sample is measured.

The method is described in detail in ISO 8833.

(g) Magnetics Content Analyzers

Magnetic Chute:

Several alternatives have been designed for determining efficiency of wet magnetic separators used in heavy media coal or mineral washing plants.

A sloping non-magnetic frame contains a permanent magnet unit above which a hinged non-magnetic tray is fitted. Slurry containing the magnetic particles is poured onto the tray and the magnetic content is held by the magnet.

The hinged tray is lifted so that the magnetics are removed from the magnetic zone and are washed off for analysis. See Figure 5-10.

Accessories provided are: rubber tube with fine jet attachment, two sample containers (not when equipment is exported), 500cc beaker, evaporating dish.

Davis Tube:

Eriez' Davis Tube Tester Model EDT (See Figure 5-11) is a laboratory unit used specifically for determining the ferro-magnetic and non-magnetic fractions of small samples of crushed magnetic iron ore, magnetite, pyrrhotite, etc. It is helpful in determining mesh of liberation, selectivity index, grade and recovery of ferro-magnetic compounds. In operating plants, it serves as a control device to determine plant concentrate and tailing quality. Field intensity of 4000 gauss in the centre of the gap of the Tester guarantees superior performance and consistent results. Variable speed of oscillation from 1 to 90 cycles and adjustable angle of operation from horizontal to 45° provide flexibility to suit established laboratory procedures and personal preference. Tube rotation of 120° and stroke of 50 millimetres are fixed standards. It is simple to operate and reproducible results are readily obtainable. The mode of operation is as follows:

With the magnet energized, a dry magnetite sample is introduced to the water-filled tube. The tube is then oscillated while a gentle flow of water through the tube washes out non-magnetics. Magnetics are caught and held in the tube between the magnet poles. After sufficient washing the tube is removed from the separator and the magnetics are flushed out, collected and dried.

Equipment furnished with the tube are:
1 extra glass tube; 1 (3 m) rubber hose; 2 hose clamps; 2 aluminum pans; 1 measuring cup; and 1 rubber stopper (51 mm) in diameter.

ISO Method:

This apparatus consists of a vertical glass tube of 8 millimetres nominal diameter and 500 millimetres in length. Two ceramic permanent magnets of more than 60 milli Tesla are located at the centre point of the tube, and both the tube and the magnets are supported on a laboratory retort stand, as shown in Figure 5-12.

The apparatus is filled with the suspension (2 grams) containing the magnetite. The contents are then drained into a 100 ml beaker. The magnets are moved up and down for cleaning (upgrading) the arrested magnetite during drainage. When the tube is drained, the magnets are removed and the captured magnetite is washed into another beaker. This procedure is described in detail in ISO 8833.

(h) Viscometers

Various rotational and capillary viscometers have been used by previous researchers in studies of heavy media viscosity. The majority have received critical comment and several unsuccessful attempts have been made to cross correlate the results obtained.

Capillary Viscometers:

DeVaney - Shelton consistometer:

This instrument is shown in Figure 5-13. It is basically an efflux viscometer with an internal stirrer to maintain homogeneity. Being an efflux viscometer, the viscosity is determined at a single point with an unknown shear rate, by comparison with a known Newtonian liquid. If the medium being investigated is at all non-Newtonian in character, the results will be meaningless.

Rotational Viscometers:

1. Rotational Viscometers

Several investigators have elected to use unmodified rotational viscometers and to neglect the settling of the unstable media. Lilge also measured the viscosity of heavy media up to a shear rate of 1000 seconds, whereas Clarke has observed that some centrifuging of particles at high shear rates led to slip on the inner cylinder and this could account for apparent discrepancy of results at high shear rates.

2. Modified Stormer Viscometer

A Stormer viscometer in contrast to a conventional rotational viscometer applies a constant shear stress to the fluid in the annular gap and measures the speed of rotation (proportional to shear rate). The modified Stormer consists of a multi-bladed rotor, rotating in the opposite direction to and also beneath the inner cylinder. This propels the fluid downward past the inner cylinder and returns it by a series of baffles. Under these conditions, the heavy media suspension is maintained in a homogeneous state by turbulence. The viscometer is calibrated by comparing known Newtonian fluids to different shear stresses. The viscosity of a Newtonian fluid in a turbulent state does not obey the basic laws of viscosity, and the same applies to a non-Newtonian fluid in this flow condition.

Measurements of viscosity made at Mintek used a modified Stormer viscometer. This instrument was modified by placing an impeller in the bottom of a water-jacketed container to maintain a uniform suspension. This container replaced the ordinary sample cup of the viscometer. The impeller was rotated by an external shaft connected to a motor with a variable-speed control, the average rotational speed used during the measurements 500 revs/min. The correct operating method and the possible factors that could cause errors, as well as the fact that slurries behave as non-Newtonian solutions, is still being investigated at Mintek as a separate project. Until such time as those investigations are complete, the measurements made are regarded as being purely comparative. The fluid used for comparison was water at 19°C, and the calculations were based on the viscosity of water at that temperature.

The formula used for the calculation of the viscosity is:

$$\eta = Wt/A$$

where W is the mass,
t is the time taken for a specific number of revolutions, and
A is the system constant.

This formula does not correct for the non-Newtonian behaviour of the suspension.

(i) Stability Testing

F5 Index Stability Method:

The laboratory method described was developed by the National Institute for Coal Research (NCIR), formerly the Fuel Research Institute, and is in general use in South Africa and Britain. A sample of the medium is placed in a copper tube (Figure 5-14), adjusted to a constant height by the use of tapping point 1, and the medium in Part 1 of the tube is run off quickly. After a settling time of 5 minutes, the medium in Part A of the tube is run off into a beaker and weighed. The medium in Part 2 of the tube is discarded, and that in Part B of the tube is retained and weighed. The mass ratio of the medium in Part A to the medium in Part B of the Tube is the calculated to give the F5 index.

The apparatus consists of a copper tube (the tube must be made of copper or another completely non-magnetic material) with an overall length of 1.225 meters (See Figure 5-14).

The main portion, which has an outer diameter of 31.75 millimetres and a inner diameter of 28.6 millimetres, is 1.14 meters in length. The common portion has an inner diameter of 12.7 millimetres and a length of 70 millimetres. The reducing piece between the main and bottom portions is 14 millimetres in length.

There are three tapping points in the side of the main portion, all of which are made of copper tubing with an inner diameter of 12.7 millimetres.

1. Calibration of the Equipment:

   (a) Stand the tube in a vertical position;
   (b) Fill the tube with clean water;
   (c) Discard the water in Part 1 of the tube (Figure 5-14);
   (d) Run off the water in Part A of the tube into a beaker, weigh the beaker, and mark it 'A';
   (e) Discard the water in Part 2 of the tube;
   (f) Run off the water in Part B of the tube into a second beaker, marked 'B', and weigh.

2. Determination of the F5 Index:

   (a) Mix the magnetite (or medium) under test with water to form a slurry with a relative density of 1.5 (Note 1);
   (b) Stand the tube in a vertical position and fill with medium;

(c) Run off the portion of medium in Part 1 of the tube as quickly as possible;
(d) Make a note of the time;
(e) Allow the medium to settle for 5 minutes;
(f) Run off the medium in Part A of the tube into the beaker marked 'A', and weigh;
(g) Discard the medium in Part 2 of the tube;
(h) Run off the medium in Part B of the tube into the beaker marked 'B', and weigh;
(i) From the mass of beaker A, as determined in step (e) above, deduct the mass of beaker A as determined in step (d) of Section (1.). This is then the mass of the magnetite in Part A of the tube;
(j) Using the same procedure, determine the mass of magnetite left in Part B of the tube after a settling time of 5 minutes.

3. Calculation:

The F5 index is calculated as follows:

If the mass of the magnetite in Part A of the tube (after subtraction of the mass of the beaker and water)

= 40 g

and the mass of the magnetite in Part B = 120 g

$$\text{the F5 index} = \frac{\text{mass of magnetite in A}}{\text{mass of magnetite in B}} \times 100$$

$$= \frac{40}{120} \times 100$$

4. Interpretation of the F5 Index:

Less than 10	Medium unstable, settling-out in bath (Note 2)
10 to 20	Medium requires stabilizing (superfine magnetite or clay) (Note 2)
20 to 30	Stability suitable for high-gravity systems (1.6 to 1.9)
30 to 60	Best working range for bath medium
Greater than 60	Medium very stable and probably too viscous.

Note:

(1) Other densities can be used, but it is important that the index should be determined and compared with one obtained at the same medium density.

(2) To increase the F5 index, increase the grinding time in the ball mill, or reduce the charge in the ball mill and maintain the same grinding time. Ensure that the demagnetizer is working.

Jar Settling Tests:

Samples of magnetite are mixed with distilled water to which a wetting agent has been added. It is essential that no residual magnetic effect is present in the test sample, and therefore the sample must be demagnetized. A suspension of concentration 1,500 kg/m^3 is usually tested and the relationship between height and time produces a settling curve with a period of uniform (linear) settling from which the settling rate in millimetres/minute is determined from the slope. Typical rates of 10-20 millimetres/minute.

A settling jar of 500 ml capacity or greater is preferable to minimize wall effects.

(j) Magnetic Properties Testing

Satmagan Balance:

This balance measures the deflection in the mass of a magnetic material upon being placed in a magnetic field. A certain amount of a sample is placed in a glass tube on a balance pan. There is a tare control knob with which the mass of the sample can be balanced exactly so that the deflection indicator rests at zero. The magnets are then swung into place, one on either side of the sample, and the measuring knob is rotated until the deflection indicator once more rests at zero. The susceptibility can then be read off the dial on the measuring knob.

A device similar to the Satmagan Balance and designed by Eaton has been used by Mintek.

The apparatus (Figure 5-15) has the advantage that any top-loading balance can be used, and the principle of operation is the same as for the Satmagan Balance.

The problem in the measurement of the magnetic susceptibility of ferromagnetic materials is that the magnetic field used must exceed the saturation magnetization of the material.

The Eaton's apparatus was constructed by the use of two magnets. The magnets had a face-value field of 2.9 kGaus, and the field measured in the centre of the air gap between the magnets was 1.9 kGaus. The results for the sample had to be compared with those for a material of known susceptibility. In this instance, mercury tetrathiocyanatocobaltate, prepared according to the method given by Figgis and Nyholm, is used. Three grams of this material are accurately weighed into a glass tube of 9 millimetres inner diameter. The yoke with the magnets is placed on the balance, and a reading is obtained. The sample in the glass tube is passed through a demagnetizing coil, clamped into the holder, and then swung into the centre of the air gap between the magnets, and a second reading is obtained. The procedure is then repeated with 1 gram of magnetite; the deflection or difference in mass between the two readings obtained in each test being used for the following calculation of the susceptibility of the magnetite.

Vibrating Sample Magnetometer:

This apparatus was used by Parry and Caddy at the University of New South Wales in Australia to characterize magnetite from different sources. Measurement of magnetic susceptibility, saturation moment, remanence and coercive force is available from each test sample.

(k) Demagnetization Test

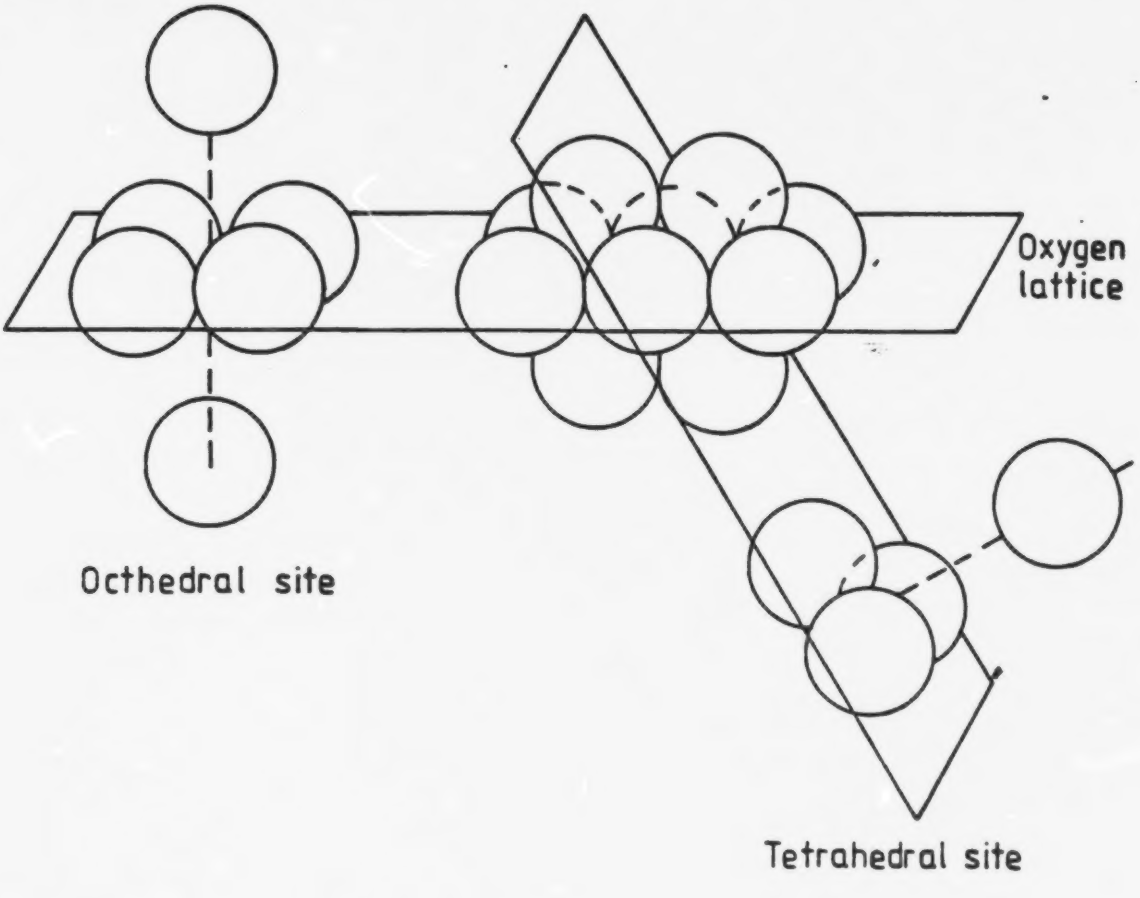
Simon-Carves Demagnetization Method:

A slurry of relative density 1.6 grams per cubic metre is prepared and placed in a 100 cubic metres graduated measuring cylinder equipped with a stopper. The flask is thoroughly agitated and then placed on a level surface, a stopwatch being started at the same moment. The settling time required for all the solids to settle through a given number of gradations is then measured and the settling rate calculated. The cylinder is passed through a magnetizing field of 2 x $10^5/$ A/m (800 oersted), and the settling rate is measured again. The cylinder is then passed through a demagnetizing field, and the test repeated. The recommended limits by Mintek for a sample that will behave well in a plant environment are as follows:

Initial setting rate - 2.0 to 6.5 mm/min
Magnetized settling rate - 200 to 250 mm/min
Demagnetized settling rate - 2.0 to 7.5 mm/min

The test was found to be very reproducible by Mintek.

FIGURE 5-1: TETRAHEDRAL AND OCTAHEDRAL SITE IN THE OXYGEN LATTICE OF THE MAGNETITE CRYSTAL


Oxygen
lattice
Octhedral site
Tetrahedral site

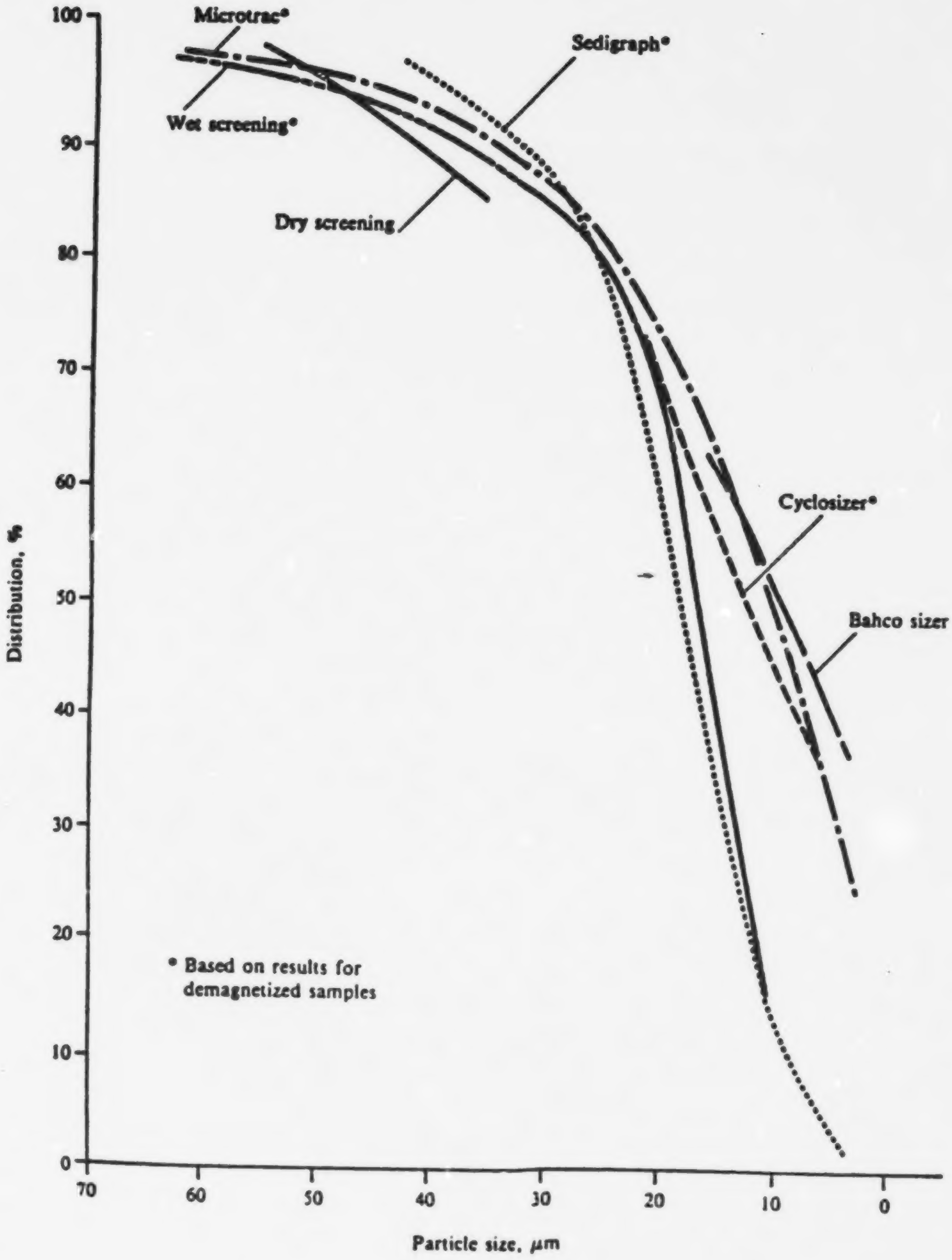
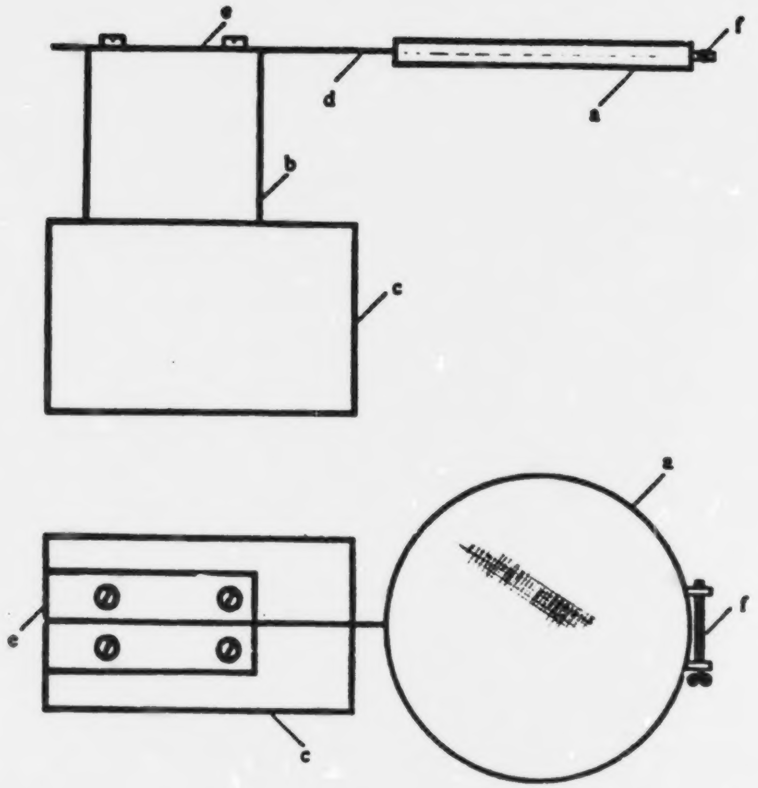


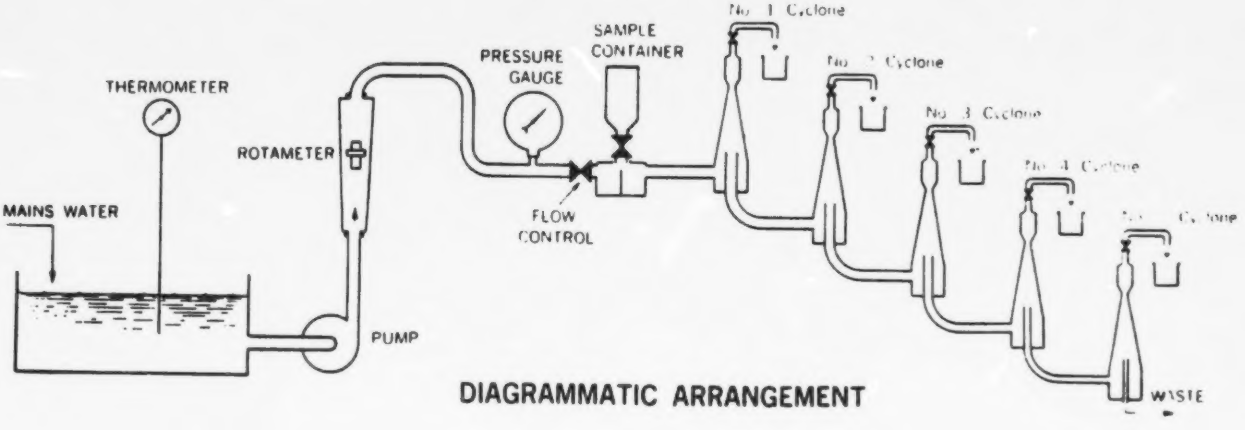
FIGURE 5-2: PARTICLE-SIZE DISTRIBUTION OF MAGNETITE



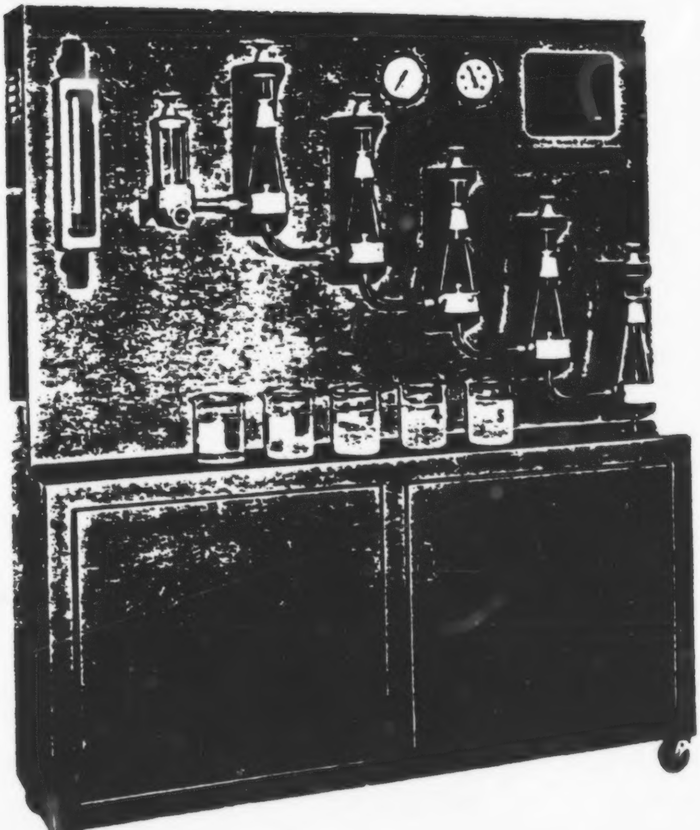
a = Adjustable ring
b = Magnetic vibrator
c = Base of heavy metal
d = Steel rod of 8 mm diameter
e = Steel plate and bolts
f = Adjusting screw

FIGURE 5-3: MINTEK WET-SIEVE APPARATUS

FIGURE 5-4: WARMAN CYCLOSIZER


THERMOMETER
MAINS WATER
ROTAMETER
PUMP
PRESSURE GAUGE
FLOW CONTROL
SAMPLE CONTAINER
No. 1 Cyclone
No. 2 Cyclone
No. 3 Cyclone
No. 4 Cyclone
Cyclone
WASTE

DIAGRAMMATIC ARRANGEMENT



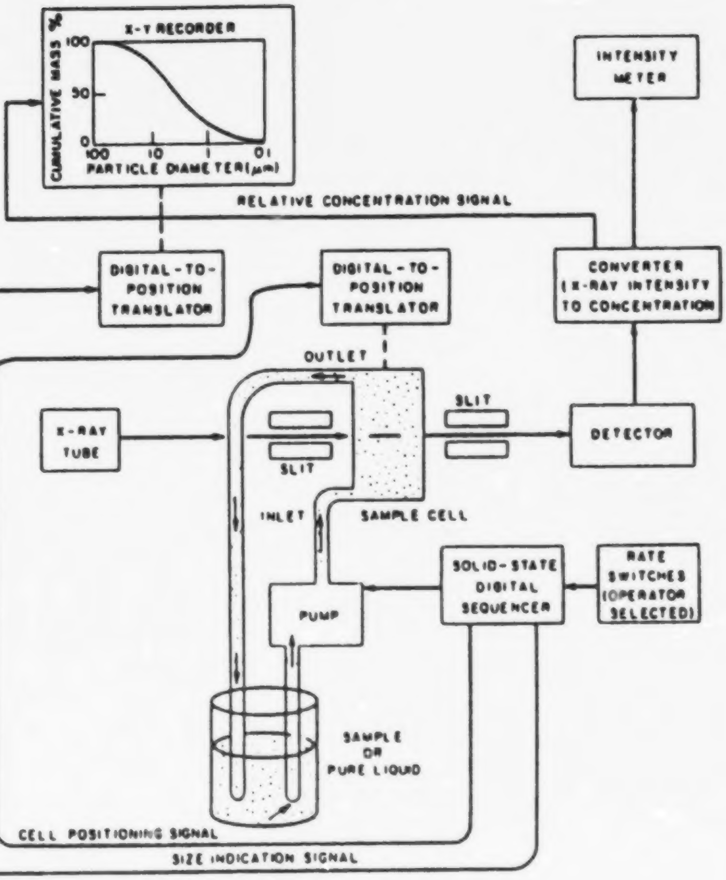

X-Y RECORDER
CUMULATIVE MASS %
100
50
0
100
10
1
0.1
PARTICLE DIAMETER (μm)
INTENSITY METER
RELATIVE CONCENTRATION SIGNAL
DIGITAL-TO-POSITION TRANSLATOR
DIGITAL-TO-POSITION TRANSLATOR
CONVERTER (X-RAY INTENSITY TO CONCENTRATION)
OUTLET
SLIT
X-RAY TUBE
SLIT
DETECTOR
INLET
SAMPLE CELL
SOLID-STATE DIGITAL SEQUENCER
RATE SWITCHES (OPERATOR SELECTED)
PUMP
SAMPLE OR PURE LIQUID
CELL POSITIONING SIGNAL
SIZE INDICATION SIGNAL

FIGURE 5-5: DIAGRAM OF THE PRINCIPLE OF THE SEDIGRAPH

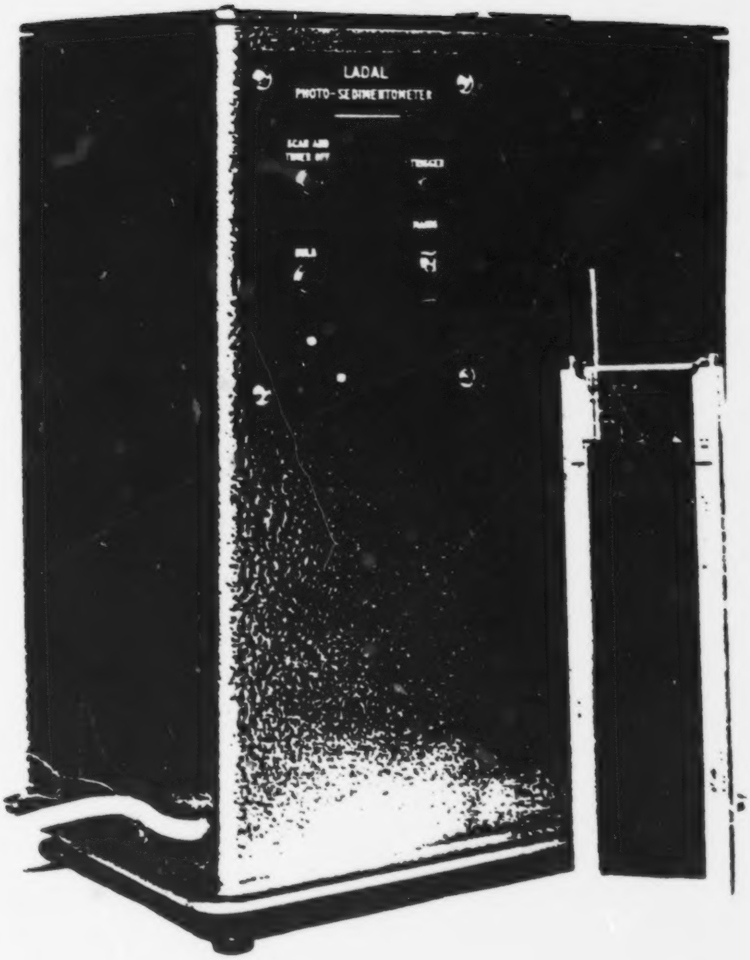
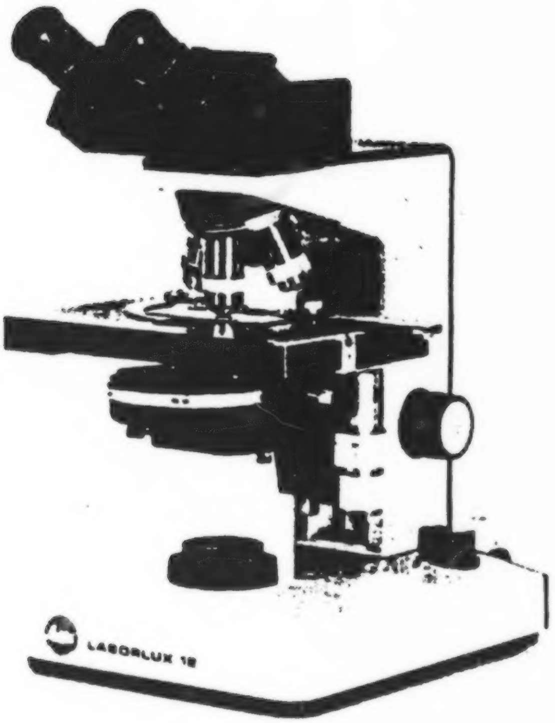

LADAL
PHOTO-SEDIMENTOMETER

FIGURE 5-6: LADAL WIDE ANGLE SCANNING PHOTO-SEDIMENTOMETER (WASP)



LABORLUX 12

FIGURE 5-7: LEITZ OPTICAL MICROSCOPE FOR PARTICLE SIZE MEASUREMENT

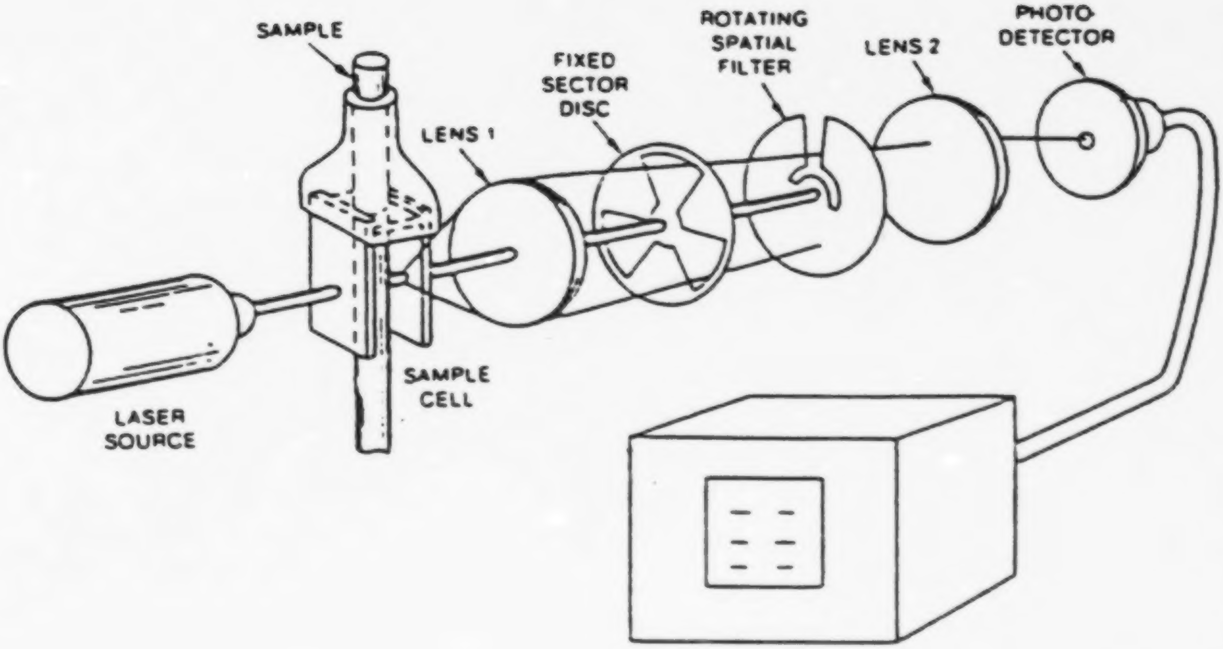

SAMPLE
ROTATING SPATIAL FILTER
LENS 2
PHOTO DETECTOR
FIXED SECTOR DISC
LENS 1
LASER SOURCE
SAMPLE CELL

FIGURE 5-8: DIAGRAM OF THE PRINCIPLE OF THE LEEDS AND NORTHRUP MICROTRAC

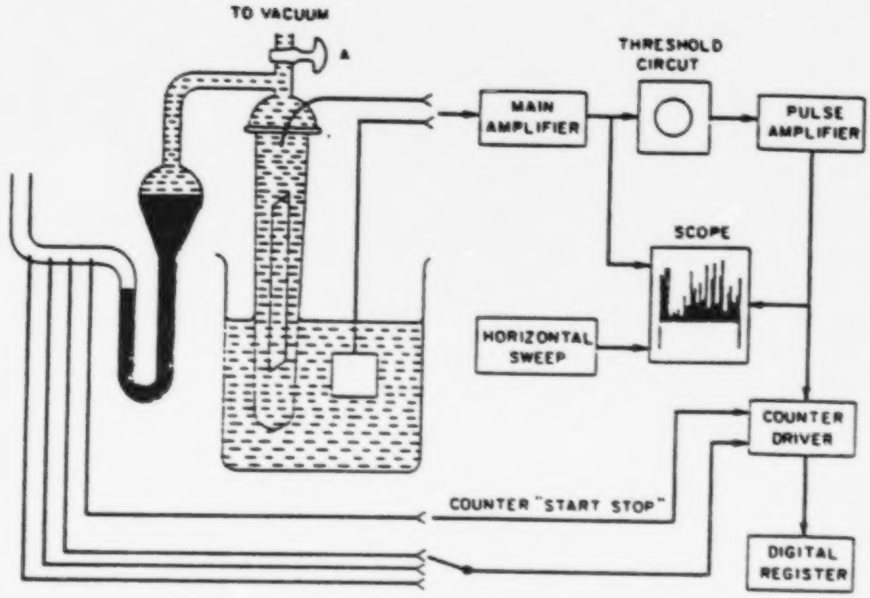

TO VACUUM
A
THRESHOLD CIRCUT
MAIN AMPLIFIER
PULSE AMPLIFIER
SCOPE
HORIZONTAL SWEEP
COUNTER DRIVER
COUNTER "START STOP"
DIGITAL REGISTER

FIGURE 5-9: DIAGRAM OF THE PRINCIPLE OF THE COULTER COUNTER

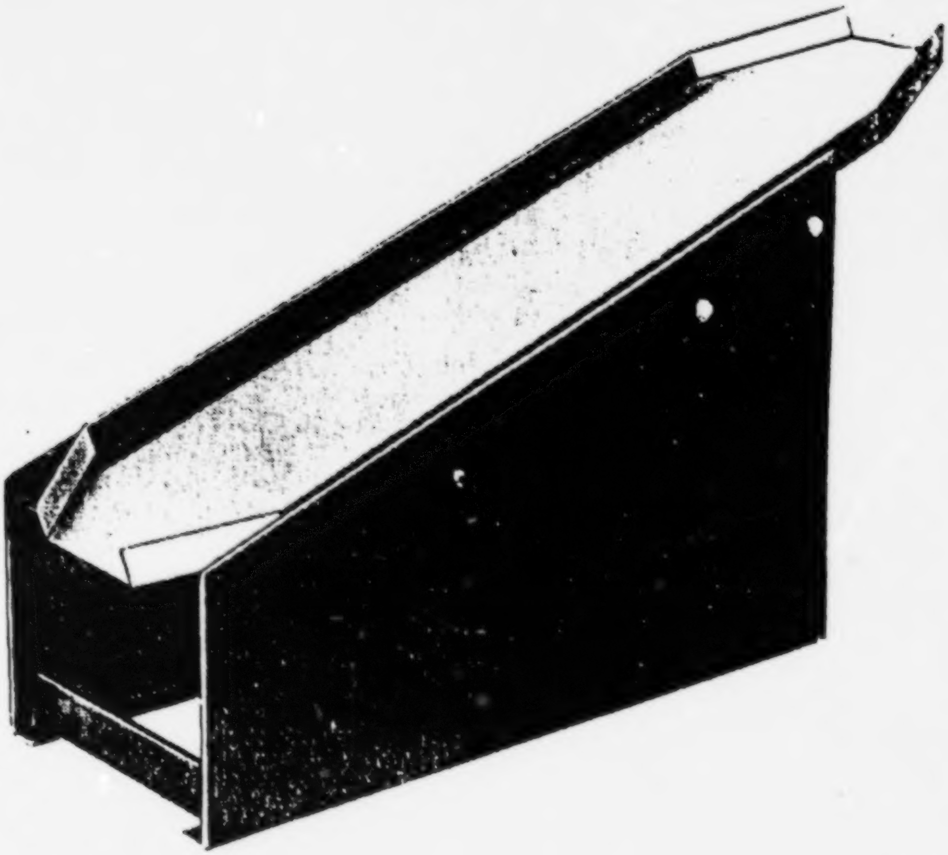


FIGURE 5-10: BOXMAG-RAPID MAGNACHUTE

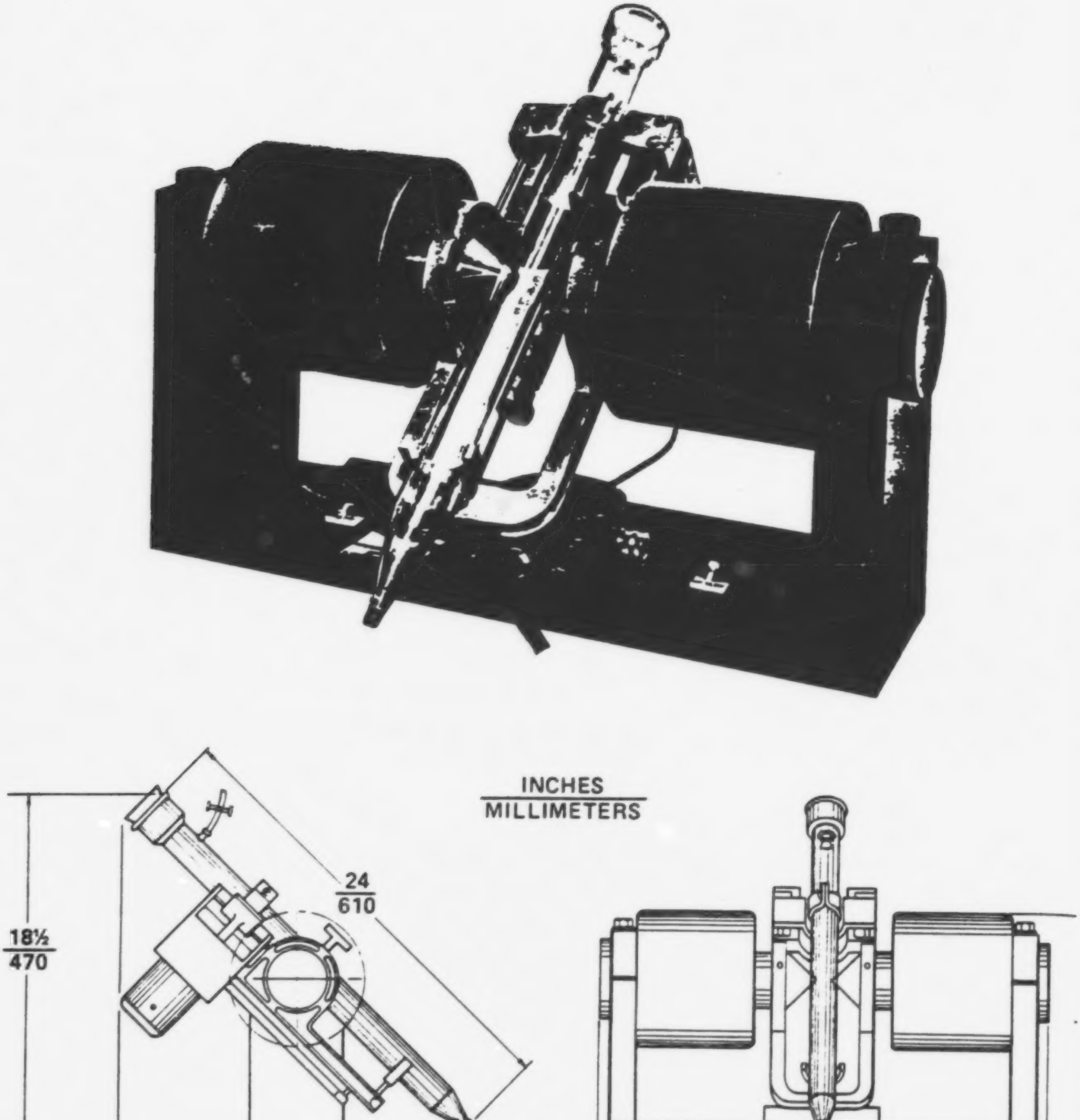

INCHES
MILLIMETERS
24
610
18½
470
6
152
26
660
MAXIMUM
25½
648

FIGURE 5-11: ERIES DAVIS TUBE APPARATUS

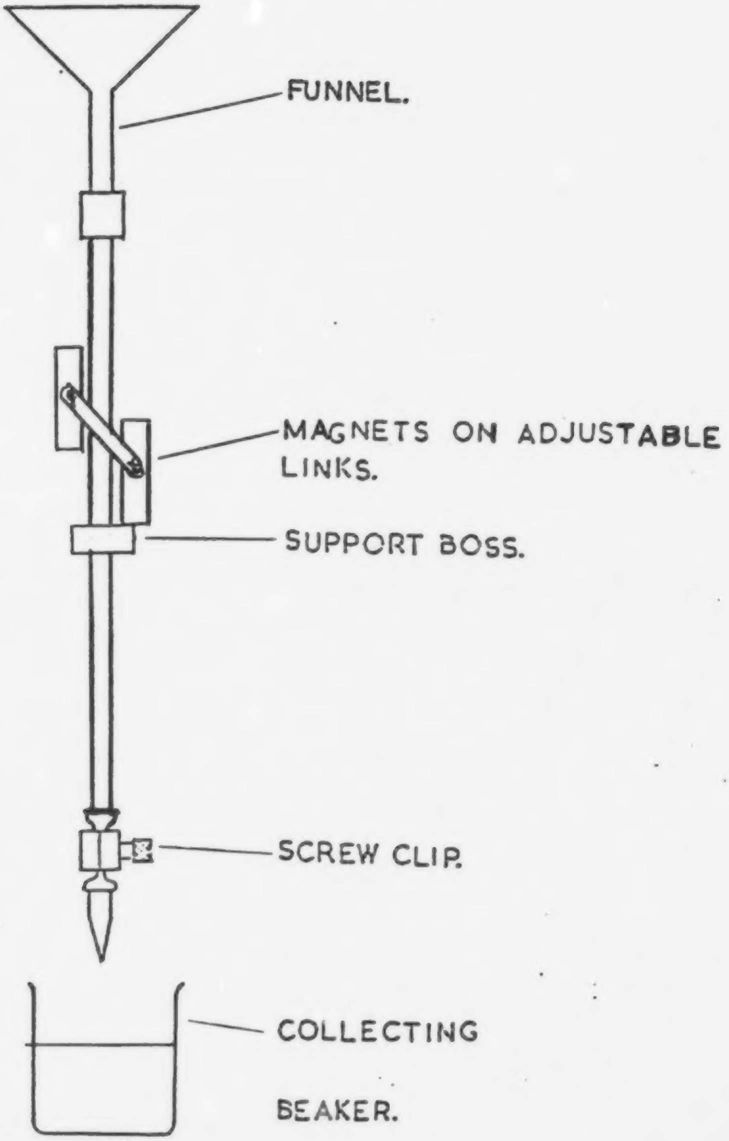

FUNNEL.
MAGNETS ON ADJUSTABLE LINKS.
SUPPORT BOSS.
SCREW CLIP.
COLLECTING BEAKER.

FIGURE 5-12: ISO MAGNETICS ANALYZING APPARATUS

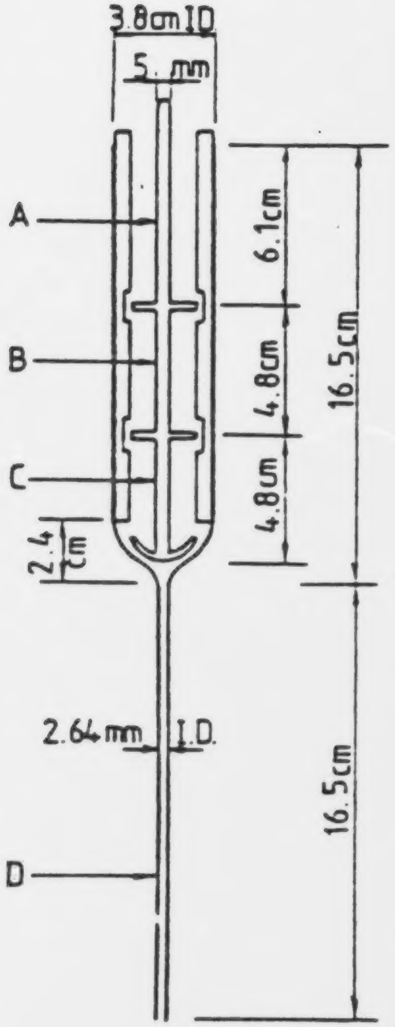
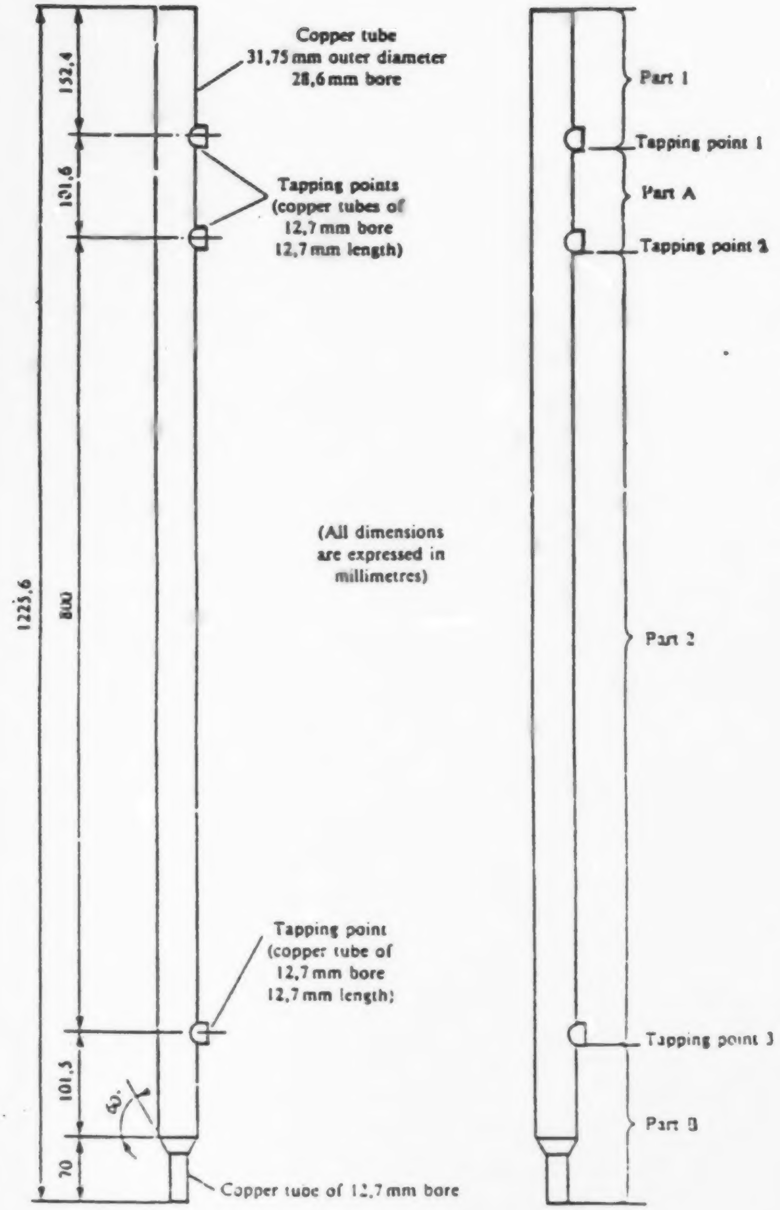
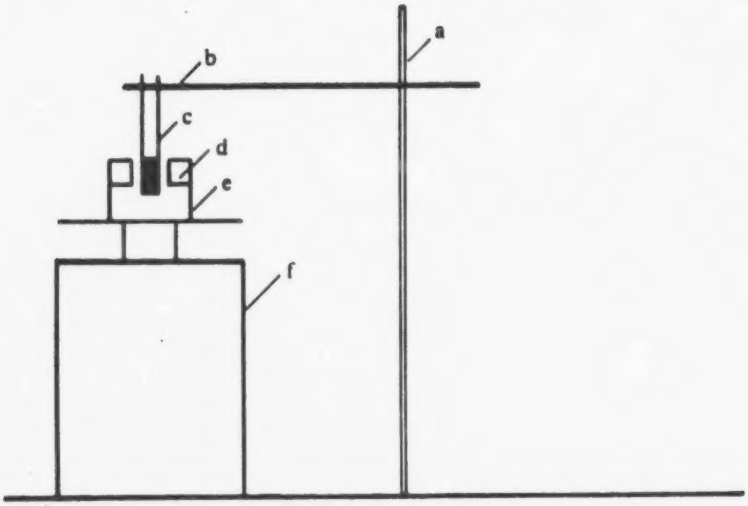

3.8cm ID
5. mm
A
B
C
D
6.1cm
4.8cm
4.8cm
16.5cm
2.4 cm
2.64mm I.D.
16.5cm

FIGURE 5-13: DEVANEY-SHELTON CONSISTOMETER


152,4
101,6
800
1225,6
101,5
70
60°
Copper tube
31,75 mm outer diameter
28,6 mm bore
Tapping points
(copper tubes of
12,7 mm bore
12,7 mm length)
Tapping point
(copper tube of
12,7 mm bore
12,7 mm length)
Copper tube of 12,7 mm bore
Part 1
Tapping point 1
Part A
Tapping point 2
Part 2
Tapping point 3
Part B

(All dimensions are expressed in millimetres)

FIGURE 5-14: F5 INDEX APPARATUS



a = Laboratory stand
b = Non-magnetic clamp
c = Glass sample tube
d = Lanthanet magnets, 7 mm thick with a diameter of 19 mm
e = Mild-steel yoke, 50 mm high with a base of 31 mm
f = Top-loading balance

FIGURE 5-15: EATON MAGNETIC SUSCEPTIBILITY APPARATUS

REFERENCES - SECTION 5.0

T. Allen	'Determination of the Size Distribution and Specific Surface of Fine Powders by Photo-Extinction Methods.' Powder Technology, V2, pp. 132-153, 1968-69.
T. Allen	'Particle Size Measurement.' 2nd Edition, Chapman and Hall, London, 1978.
Anon.	'Dense Medium Coal Preparation.' Simonacco Ltd. Publication, 1968.
D. Birlingmair, et al	'Characterization and Performance Evaluation of Fly Ash Derived Heavy Medium Material.' US DOE Report IS-4839, March 31, 1983.
C. C. Graham	'The Application of Magnetite for Coal Preparation in Australia.' Paper 82-349, 1st Int. SME of AIME Meeting, Honolulu, Hawaii, September, 1982.
C. C. Graham and R. Lamb	'Coal Preparation - Dense Media Rheology: A Review of Measurement and Control.' ACIRL Research Report. P.R. 82-3. April 1982. (Australia).
K. Komorniczyk, et al	'Viscosity, Stability and Corrosion of Ferro Magnetic Media Used in Sink-Float Separation Process.' Source unknown.
J. Morgan and L. G. Parry	'The Nature and Properties of Magnetite.' ACIRL Research Report. P.R. 68-3, 1968. (Australia).
A. Muller	'Characteristic Properties of Magnetite as a High-Gravity Solid for the Heavy-Medium Separation of Coal.' (In German). Aufbereitungs-Technik - Nr 5/1985, pp. 259-269.
J. Rayner, et al	'Characteristics of Magnetite Suspensions With Reference to Coal Washery Performance.' Proc. Inst. Fuel. Biennial Conference, November 1976.
L. H. Savage	'The Selection and Treatment of Magnetite for Use in Dense Medium Coal Preparation.' ACIRL Research Report. P.R. 68-5, 1968. (Australia).
L. Valentyik	'Rheological Properties of Heavy Media Suspensions Stabilized by Polymers.' Trans. Soc. Mining Engineers, AIME, March 1972, pp. 99-105.

P. J. van der Walt	'Materials Available in South Africa for Use as Dense Media.' Paper 11, 2nd Symp. on Coal Preparation, University of Leeds, October 1957, pp. 285-304 (including discussion).
H. F. Yancy, et al	'Viscosity, Its Measurement and Importance in Dense-Medium Cleaning of the Fine Sizes of Coal.' 3rd Int. Coal Preparation Congress. Paper F1, pp. 584, Liege, 1958.

6.0 TESTING AND EVALUATION PRACTICES

6.0 TESTING AND EVALUATION PRACTICES

6.1 GENERAL

Current practices and procedures in the preparation and use of magnetite as a coal cleaning heavy media are not widely publicized. Kilborn therefore decided to contact several international coal research establishments in order to obtain the latest available information, and this Section of the Report describes the response received. Based on these responses, the statistics in Table 6.01 were compiled.

6.2 INTERNATIONAL PRACTICE

Responses were obtained from the following organizations which were contacted regarding methods for testing magnetite:

Australia	- Australian Coal Industry Research Laboratories (ACIRL).
	- BHP Research and Technology.
Great Britain	- Mining Research and Development Establishment of the National Coal Board (MRDE).
	- Royal School of Mines (RSM).
Netherlands	- Stamicarbon bv.
South Africa	- National Institute for Coal Research of CSIR.
	- Council for Mineral Technology.
United States	- Pittsburgh Energy Technology Center of DOE.
	- Homer City Laboratory of Penelec.
	- Ames Laboratory, Iowa State University.
West Germany	- Steinkohlenbergbauverein.
	- Saarbergwerke AG.

Although there are no specific national or international standards for testing magnetite presently in use, there is much activity in the development of such standards.

The most notable of these endeavors is the recently produced Draft Proposal ISO/DP 8833, Document ISO/TC 27/SC IN 222 E entitled, 'The Testing of Magnetite for Use in Coal Preparation'. This is the second draft and was issued in early 1985. A final draft is currently in preparation which will be voted on by the spring of 1986 for issue later this year. Other known attempts at producing standards for magnetite testing include:

(a) A standard Davis tube test method in preparation by a Coal Task Group for ASTM (U.S.A.);
(b) A standard specification for magnetite use in NCB (U.K.) coal preparation plants;
(c) Standard procedures for the evaluation of magnetite for use in all heavy media separation processes by MINTEK (RSA);
(d) A standard specification for magnetite use within the Australian coal industry;
(e) A method for determining the settling behaviour of magnetite medium by Saarbergwerke AG of West Germany.

With regard to the normal user standard for delivered magnetite of heavy media grade, there is almost universal agreement in current practice. The size distribution specified is almost always closely related to the original Dutch State Mines' specification for heavy media cyclone operation, i.e., 95 percent minus 40 microns. Other specified parameters are based upon practices established by the early European users and typified by the current NCB of Britain magnetite specification, i.e.:

(a) Relative density > 4.85

(b) Magnetic content $>$ 97 percent
(c) Size fraction below 60 micron $>$ 85 percent
(d) Size fraction below 10 micron $<$ 10 percent
(e) Moisture content $<$ 10 percent.

All of the countries surveyed, more or less comply with the above specification, i.e.:

(a) Australia
(b) Canada
(c) Poland
(d) South Africa
(e) United States
(f) West Germany.

6.3 INTERNATIONAL STANDARD (ISO 8833)

This document is still in preparation and is due to be finalized later in 1986. It was specifically prepared for the purpose of identifying the essential requirements of a magnetite to be used in a heavy media suspension, and setting down suitable tests using simple apparatus where possible.

Although moisture content, size distribution, magnetic content and relative density are generally considered adequate for routine checking of regular supplies, extra tests have been included in the document as they may be necessary for evaluating new sources of magnetite.

The Standard specifies procedures for both sampling and testing of magnetite, and the specified tests are intended primarily for the testing of milled magnetite, the top size of which is assumed to be below 250 microns. It is possible to apply the tests to unmilled magnetite with a top size limit of about 500 microns.

The specified tests should ensure that the properties which make magnetite suitable for heavy media usage are acceptable. These properties are:

(a) Moisture content;
(b) Particle size distribution;
(c) Magnetic content;
(d) Relative density;
(e) Fundamental magnetic properties, i.e., coercive force, remanence, susceptibility and saturation magnetic moment;
(f) Total iron content;
(g) Ferrous iron content.

The Standard recommends that all of the tests included for the determination of the above properties should be conducted in order to assess magnetite from a new source, but for routine checking of regular supplies only, the tests for (a) to (d) should be necessary.

The specific test methods recommended for each determination are as follows:

Sampling - should be carried out in accordance with the general recommendations of ISO 3081, 'Iron Ores - Increment Sampling - Manual Method'. The mass of sample required to perform the tests is obtainable from ISO 3083, 'Iron Ores - Preparation of Samples'.

Moisture Content - is obtained by drying either one kilogram of sample from a large consignment, or 100 grams (minimum) of a laboratory test sample, using a laboratory air oven capable of being maintained within a temperature range of 105°C to 110°C.

Particle Size - analysis is divided into two ranges:

(a) sieve;
(b) sub-sieve.

The distinction is stated as being 38 micron woven wire aperture.

Sieve analysis is performed in accordance with ISO 565, 'Woven Wire Cloth Test Sieves', and ISO 3310, 'Test Sieves - Technical Requirements and Testing'. The number of sieves required would be determined by the grain size range, but will usually be between 250 and 38 microns. The mass of each test portion would not be less than 25 grams and not more than 100 grams. Wet sieving is the preferred method.

Sub-sieve analysis techniques recommended are those employing centrifugal classification, e.g., Warman Cyclosizer. Sedimentation and elutriation methods are affected by the agglomeration tendency exhibited by magnetite particles in suspension. The mass of test portion would not be less than 10 grams and usually not more than 50 grams (depending on the method).

Magnetic Content - the preferred test method employs the special apparatus described in the previous Section of this Report and shown in Figure 5-12. Alternatively, the Davis magnetic tube tester may be used. Sample portions of between 2 and 5 grams are suggested.

Relative Density - should be determined using the relative density bottle method in which the volume of liquid displaced by a known mass of sample (15 grams) is measured. The preferred liquid is distilled water as this results in a more direct method less liable to measurement error. Alternatively, methylated spirits may be used.

Fundamental Magnetic Properties - the Standard suggests that the determination of suitable parameters requires specialized apparatus and suggests such work be carried out by a university or research institute. There was apparently a lack of consensus as to which magnetic parameters are relevant in the context of the Standard. It was therefore left open for users to decide for themselves, but the Standard does suggest that coercivity is a guide to the ease of recovery, and saturation magnetic moment is a measure of the purity of the individual grains.

Total Iron Content - should be determined using the volumetric method specified in ISO 2597 (Method 1b), 'Iron Ores - Determination of Total Iron Content - Volumetric Method'. The test portion is about 0.25 grams.

Ferrous Iron Content - should be determined by dissolving the test sample (0.25 grams) in hydrochloric acid under a nitrogen atmosphere and titrating the ferrous iron taken into solution with standard potassium dichromate.

6.4 INTERNATIONAL TEST APPROACHES

Information regarding current methods evaluating and testing magnetite for heavy media application was received from various organizations throughout the world. Details of these responses are included in Appendix 'A', but a summary of them now follows:

6.4.1 National Coal Board of Great Britain (NCB)

The NCB apparently intends to adopt the ISO Magnetite Standard as its working standard as soon it is issued. It is also in the process of preparing a 'Specification for Magnetite' which specifies:

- The relative density determined on the dry basis, shall be not less than 4.85 RD;
- The magnetic content determined on the dry basis shall be not less than 97 percent by weight;
- The fraction below 60 micron size determined on the dry basis shall not be less than 85 percent by weight;
- The fraction below 10 micron size determined on the dry basis shall not exceed 27 percent by weight in any one consignment, and the weighted average over each 12-month period shall not exceed 25 percent;
- The moisture content at the time of shipment from the foreign port shall not exceed 10 percent;
- The chemical composition of the magnetite as loaded including impurities and trace elements, etc., shall in no way render it hazardous to operators, or unsuitable for use as the solids fraction of heavy media suspensions in the Board's Coal Preparation Plants.

6.4.2 National Institute for Coal Research of South Africa (NICR)

Although coal production occurs in both public and private sectors in South Africa, coal sampling and testing procedures are generally established by or through NICR, and practices are carefully monitored by the Institute. This approach is greatly encouraged by the larger coal mining companies such as AMCOAL, General Mining, and Rand Mines.

Consequently, methods at NICR for sampling, testing and evaluation of magnetite for heavy media coal cleaning are more or less standardized. The normal analytical procedures carried out on a fairly regular basis are:

- Magnetics content using the Davis tube;
- Size distribution analysis using the Cyclosizer. Wet sieving is carried out to minimum size of 45 microns, but

as the greater portion is less than 45 microns, the Cyclosizer is the principal analyzer;

- Relative density is measured by hydrogen pycnometer or density bottle using distilled water;
- Settling rate is measured using the F5 Index tube.

At present, NICR is also investigating other methods for settling rate determination, and also viscosity.

The South African Bureau of Standards, represented by NICR, has voted in favour of the draft ISO 8833. It is proposed to adopt this standard as general practice in South Africa when it is issued.

The Council for Mineral Technology (MINTEK) commissioned an investigation into 'The Development of Standard Procedures for the Evaluation for Use in Heavy-Medium Separation', and in 1984, a report was issued discussing their findings.

They indicated that over 116,000 tonnes is used annually in South Africa for heavy media applications, and average cost is R 285 per tonne. Much of this is used in coal cleaning because mineral separation uses ferro-silicon either with magnetite or by itself.

The general specification of coal users is as follows:

Size Distribution : Maximum 5 percent by weight larger than 45 microns and 30 percent by weight smaller than microns
Relative Density : 4.9 to 5.2 g/cm^3
Magnetite Content : Not less than 95 percent by weight.

Testing practices for dry screening, wet screening, settling rate, relative density, viscosity and the determination of magnetic properties were examined by a 'round-robin' program involving the laboratories of four organizations. These were NICR and MINTEK, and also FOSCOR and RAND MINES.

The comparison of the methods used and the results obtained by different laboratories showed that certain tests are very susceptible to a slight difference in method, and should be standardized as rigorously as possible. Tests on some properties do not depend on the method, such as those on density, and for these the most convenient method available can be used.

The recommended standard test for the evaluation of magnetite was as follows:

(a) Particle-size analysis at 25 and 45 um by use of the wet-screening method as developed at Mintek;
(b) Determination of the percentage of non-magnetic material present by use of the Davis tube, under the conditions set out by Mintek (the introduction of a circulating system and extra magnetic trap being regarded as an unnecessary complication);
(c) Determination of the density by whatever method seems suitable and is convenient;
(d) Determination of the F5 Index as set out in the previous Section of this Report;
(e) The Simon-Carves test on the ease of demagnetization;
(f) Determination of the magnetic susceptibility.

6.4.3 Australian Coal Industry Research Laboratories (ACIRL)

Australia is in a similar position to Canada in that most of its coal mining operations are in the private sector, and no official standard exists for testing and evaluating magnetite. Also, there is effectively only one source of supply of magnetite to the Australian coal industry, i.e., Mount Biggenden in South East Queensland. This supplier provides five grades of material based on the following size analysis, with price increasing with fineness:

Grade	Percent Passing 53 Micron
Coarse	50-60%
Medium	65-75%
Fine	85-90%
Superfine	92-95%
Super Superfine or Ultrafine	94-97%

Due to medium stability problems, the superfine and ultrafine grades comprise by far the majority of sales. The supplier has only one deposit, and the different grades are produced by altering the operation of the supplier's product ball mill. Because of this, the majority of magnetite testing in Australia is devoted solely to magnetite size analysis in order to determine whether the supplied magnetite is of the specified fineness.

The other general magnetite specifications are:

Specify gravity	4.9 minimum
Magnetic content (Davis tube 700 gauss)	96%
and typical chemical analysis is:	
SiO_2	1.4%
Al_2O_3	0.8%
Total Fe	69.5%
Fe_3O_4	95.0%
S	0.4%
P	0.02%
Cu	0.005%
H_2O (110°C)	10% max.

ACIRL, in representing the Australian coal industry, has been instrumental in the development of the new ISO 8833 standard.

It is the Australian secretariat which is monitoring the preparation of the final version. Consequently, it is anticipated that the Australian industry will adopt the new standard as general practice.

BHP, Australia's largest company and major coal producer, has its Central Research Laboratories at Shortland, New South Wales. This facility is a division of the parent company, and conducts a large amount of coal research. This work has recently included magnetite testing.

Despite the virtual control of the magnetite market by one supplier, a number of companies, including some with South African sources, have been attempting to enter the market. BHP has had some samples delivered to them for evaluation and, the following tests were conducted on these samples:

(a) Specific gravity determination - medium acceptable value is 4.90.
(b) Chemical analysis for Al_2O_3, CaO, CuO, Total Fe, Fe^{2+}, K_2O, Mn, NiO, P_2O_5, S, SiO_2, TiO_2, V_2O_5, ZnO and total moisture.
(c) Mineralogical examination.
(d) Size analysis via combination of sieves down to 38 microns and Cyclosizer below 38 microns.
(e) Recoverable magnetics - Davis tube at 400,550 and 700 gauss. Minimum acceptable magnetics is 96 percent at 700 gauss, but recovery should not be particularly dependent on field strength.
(f) Settling rate measurement - the settling rate of magnetite was determined from a slurry magnetite concentration of 500 grams per litre (corresponding to slurry relative density of approximately 1.40) in a measuring cylinder. This test was carried out on an 'as received' sample and a sample demagnetized by passing it through an AC coil. Generally, a superfine grade magnetite was

found to have a settling rate of about 2.5 cm per minute. The demagnetized sample was used as a check for the presence of any 'flocs' or 'stringers' of magnetite. If there was a large discrepancy between the setting rates of the 'as received' and 'demagnetized' samples, tests on the magnetic qualities of the material were then undertaken. These tests cannot be done on-site, but require fairly simple magnetic equipment. The properties measured and their acceptable values were:

Initial Susceptibility, K_{30} (emu/g)	- > 0.050
Susceptibility at 800 oersteds, K_{800} (emu/g)	- > 0.053
Saturation moment, M_{sat} (emu/g)	- > 80
Coercive force, H_c (oersteds)	- < 50

Of these four, the one which is of most significance to BHP is the coercive force. This is approximately linearly dependent upon magnetic remanence. A high coercive force usually correlates with a high-settling rate of the 'as received' material, and is commonly caused by a high level of titania. Magnetites with titania contents above one percent, are prone to agglomeration and this can cause medium stability problems in washeries not fitted with AC demagnetizing coils.

6.4.4 Pittsburgh Energy Technology Center of the U.S. Department of Energy (PETC)

Consumption of magnetite for heavy media coal cleaning in the U.S.A. in the early part of this decade exceeded 250,000 tonnes, all of which was produced domestically. Production and demand forecasts for magnetite supplies in the U.S.A. indicate that no abnormal situations are likely to occur in the foreseeable future, and production costs are low, i.e., well below $100 per tonne, complying with the specification in Table 6.01.

Sampling procedures usually comply with ASTM Part 12, but there are no standard methods for testing heavy media magnetite either in Part 12 or Part 26 (which includes coal testing and analysis).

The four main suppliers of heavy media grade magnetite, i.e., Foote Mineral, Reiss-Viking, Prince Manufacturing, and N. L. Industries all supply more than one grade of ready milled magnetite either in bulk form or in fabric bags. These commercial products are usually specified by:

- Relative density;
- Average magnetics content (by Davis tube at 550 gauss);
- Size - proportion passing 325 mesh (45 microns);
- Chemical analysis (Fe, P_2O_5, SiO_2, MnO, Al_2O_3, CaO, MgO and 5%).

Selling price is determined by the proportion passing 325 mesh and the magnetics content.

Bulk magnetite is delivered by pneumatic trucks or in bags, the latter being the more costly.

The Department of Energy (DOE) is believed to be financing research in heavy media for coal cleaning in two main areas:

(a) Study of the rheological properties of magnetite suspensions which is being carried out by PETC in Pittsburgh;
(b) Study of the use of magnetically fractioned fly ash heavy media which is being carried out by Ames Laboratory in Iowa.

A Coal Task Group of ASTM is preparing a standard method for Davis tube testing, but no other form of magnetite test standard is at present contemplated.

PETC, representing the DOE on the ISO Standards Committee, will probably abstain from voting on the final draft of ISO 8833 because it was not involved in developing the standard. PETC does not appear to regard this new Standard as being applicable to the U.S. coal industry, and it is doubtful that it will be adopted by the private sector unless it receives DOE endorsement.

User testing of supplies in the U.S.A. is varied, and only the Davis tube magnetics determination apparatus is widely employed. Size analysis is performed with a variety of different analyzers and relative density is rarely reported. Bulk density measurement appears much more common.

6.4.5 Stamicarbon bv., Netherlands

Research and development in heavy media at this organization has been largely confined to particle size analysis. In 1981, a report was issued on test work carried out with 3 dry (pneumatic) sizing devices and microform sieves with an ultrasonic bath. Two devices, the Bahco sizer and the Zick-zack sizer, were found suitable providing a standard procedure is adopted. The original work carried out at this Institute over 30 years ago led to the development of size distribution specifications for heavy media cyclones (i.e., Dutch State Mines patents for heavy media cyclone separation circuits). The DSM specified ideal circulating medium size distribution is shown in the graph in Figure 6-1.

6.4.6 Saarbergwerke AG, West Germany

FABERG, the standardization committee on Mining Engineering with the German Standards Institution (DIN) based in Essen, is engaged in preparing appropriate standards for process operating materials. At present, it is considering a method for the determination of settling characteristics of magnetite used for heavy medium which has been developed by Saarbergwerke. This is seen as a first step in producing a new standard called, 'Heavy Media: Definitions, Requirements and Testing'.

TABLE 6.01

COAL CLEANING HEAVY MEDIA MAGNETITE STATISTICS (1983)

	COAL CLEANING MAGNETITE	WORKING SPECIFICATION			
COUNTRY	ESTIMATED ANNUAL CONSUMPTION (tonnes)	MOISTURE CONTENT (%)	PARTICLE SIZE DISTRIBUTION (microns)	MAGNETICS CONTENT (%)	RELATIVE DENSITY (Kg/m^3)
CANADA	75,000	<10	<5% + 45	>95	>4800
UNITED STATES	250,000	<10	<5% + 45	>95	>4800
SOUTH AFRICA	115,000	<10	<5% + 45 <30% - 10	>95	4900-5200
UNITED KINGDOM		<10	≥85% - 60 ≤27% - 10	>97	>4850
AUSTRALIA	80,000	<10	<5% + 45 <30% - 10	>95	>4800

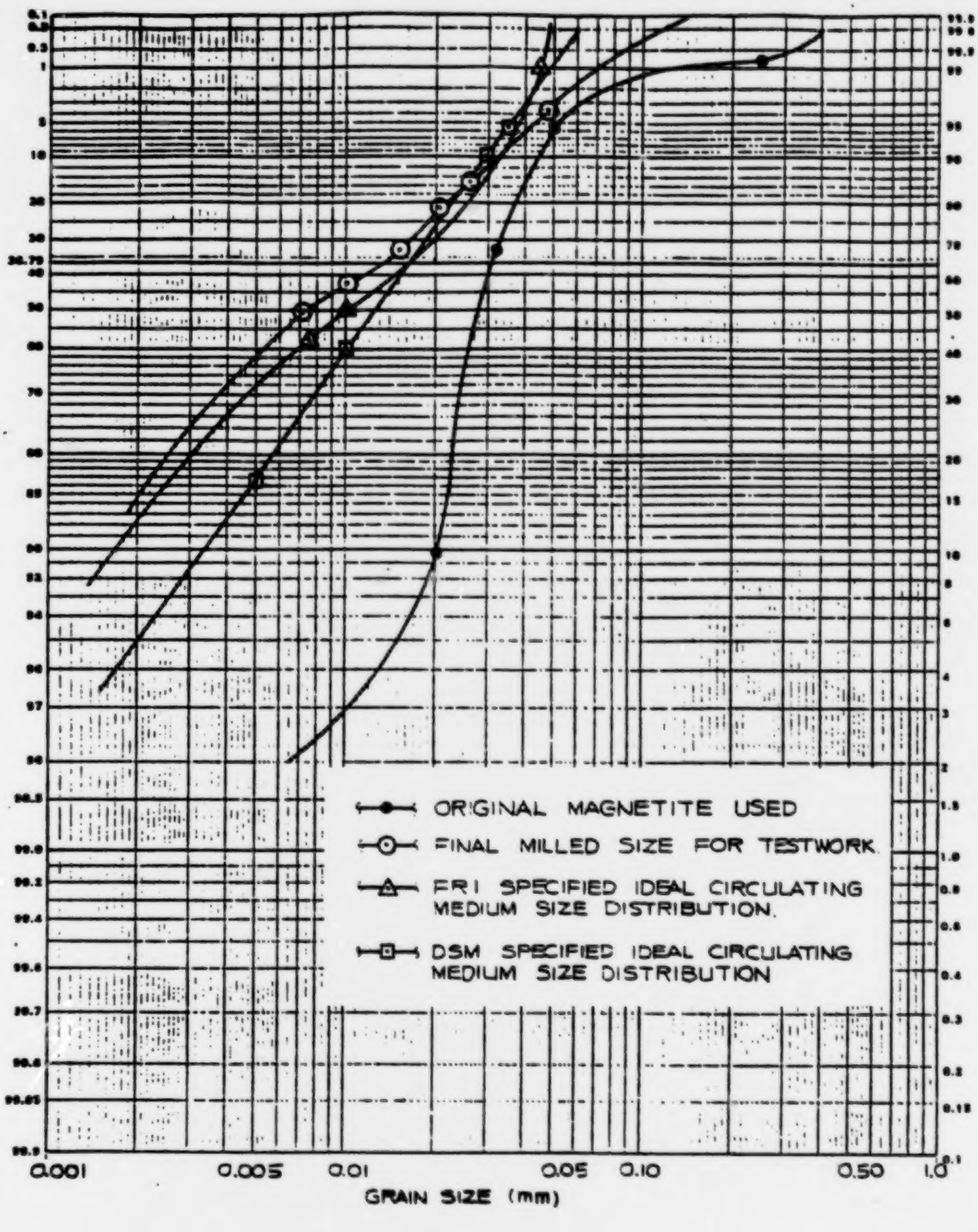


FIGURE 6-1: SIZE DISTRIBUTION CHART FOR GROUND MAGNETITE

REFERENCES - SECTION 6.0

Anon.	'Davis Tube Testing Procedure.' Source: Reiss-Viking Corporation.
Anon.	'Specification for Magnetite.' (Draft) 1985. The NCB Code of Practice for Coal Preparation.
Anon.	'The Testing of Magnetite for Use in Coal Preparation.' Draft Proposal ISO 8833, 1985.
R. Bosold	'Determination of Magnetics Content of Magnetite - Standard Procedure.' Penelec, Homer City Coal Laboratory, July 1983.
R. Bosold	'Isolation of Magnetic Material for Microsize Analysis - Standard Procedure.' Penelec, Homer City Coal Laboratory, October 1983.
J. Collong and Cruts	'Evaluation of Analytical Techniques for H. H. Determination of the Grainsize Distribution of Solid Particles in Heavy Media.' Report 19938 Stac/95-1 by Stamicarbon, November 19, 1981 (Netherlands).
C. C. Graham	'The Application of Magnetite for Coal Preparation in Australia.' Paper 82-349, 1st Int. SME of AIME Meeting, Honolulu, Hawaii, September 1982.
L. Jonker	'The Development of Standard Procedures for the Evaluation of Magnetite for Use in Heavy-Medium Separation.' Mintek Report, No. M144, May 30, 1984 (Rep. South Africa).
P. G. Meerman and H. J. Obekerken	'Sedimentation Analysis of Magnetite.' 1952. (Source unknown).
A. Muller	'Characteristic Properties of Magnetite as a High-Gravity Solid for the Heavy-Medium Separation of Coal.' (In German). Aufbereitungs-Technik, Nr 5/1985, pp. 259-269.
E. Muller	'South African Analytical Procedures for Magnetite Testing.' Private Communication dated November 13, 1985.
N. F. Schulz	'Determination of the Magnetic Separation Characteristic with the Davis Magnetic Tube.' Trans. Soc. Mining Engineers, pp. 211-216, June 1964.

ISO 565	-	Test Sieves - Woven Metal Wire Cloth and Perforated Plate - Nominal Size of Apertures.
ISO 648	-	Laboratory Glassware - One Mark Pipettes.
ISO 2591	-	Test Sieving.
ISO 2597	-	Iron Ores - Determination of Total Iron Content - Volumetric Method.
ISO 3081	-	Iron Ores - Increment Sampling - Manual Method.
ISO 3083	-	Iron Ores - Preparation of Samples.
ISO 3310/11	-	Test Sieves - Technical Requirements and Testing: Part 1 Test Sieves of Metal Wire Cloth.

7.0 CONCLUSIONS

7.0 CONCLUSIONS

In examining the information which has been collected during the first stage of this Project, the following conclusions can be made:

7.1 MAGNETITE SOURCES AND RESERVES IN CANADA

There would appear to be ample reserves of magnetite ore in Canada amenable to preparation to meet the needs for heavy media coal cleaning applications.

To cater for the coalfields in the western provinces, there are proven magnetite deposits in British Columbia and the Yukon which will come into production when the less expensive alternatives have been exhausted. Consequently, there will be a significant increase in the delivered price of magnetite within the next 5-year period.

To cater for the coalfields of eastern Canada, there are proven magnetite deposits and continuing iron mining operations in addition to a competitive U.S.A. producer in New York State.

With a total annual requirement that is unlikely to exceed 100,000 tonnes (95 percent in the western provinces), there is little likelihood that production will be unable to meet demand at any time in the foreseeable future.

7.2 MAGNETITE USAGE IN COAL CLEANING

Demand has been estimated to be 70,000 to 75,000 tonnes per year at present and could rise to 100,000 tonnes if a significant improvement in demand for export coal or domestic usage occurs within the next 10 years.

Improvements in operating practice, both in terms of the introduction of new equipment and in improved procedures for recovery of medium, will, without doubt, lead to a reduction in consumption on a tonnes treated basis.

New media recovery equipment together with special instrument and control equipment will result in improved heavy media circuit operation and lower magnetite loss.

It is possible that some of the bigger operations will opt for 'in plant' magnetite milling circuits in order to obtain:

(a) Close to ideal size distribution for each heavy media circuit;
(b) Lower overall cost in obtaining the required magnetite medium.

The implementation of standard in-plant test and analytical procedures will create a greater awareness of media requirements and, consequently, improvements in magnetite preparation and recovery.

7.3 TESTING AND EVALUATION OF MAGNETITE

With the introduction of the ISO 8833 Standard, Canadian users will have an opportunity of familiarizing operating personnel with the technical requirements for heavy media grade magnetite. Plants will be able to establish test facilities and methods for testing and analyzing magnetite, which will have good repeatability and reproducibility. Universities and research centres which have the more specialized equipment and expertise available will be able to serve the needs of suppliers and users in verifying quality specifications.

At the conclusion of this current Project, it is proposed that the basic sampling and testing needs of the plant and the more specialized test and analytical needs for detailed evaluation of magnetite will have both been identified.

APPENDIX 'A'

CORRESPONDENCE REGARDING MAGNETITE USAGE IN OTHER COAL PRODUCING COUNTRIES

National Coal Board
Ashby Road, Stanhope Bretby,
Burton-on-Trent,
Staffs. DE15 0QD.
Telephone: Burton 0283 216161
Telegrams: Coalboard Burton
Telex: 341741 CBTD G
FAX: 0283 216161 Ext. 118

NCB

Technical Department

Our Ref: 373

11 November 1985

Mr D G Osborne
Senior Coal Preparation Engineer
Kilborn Engineering (BC) Ltd
1380 Burrard St
Vancouver
Canada
V6Z 2B7

Dear David

Thank you for your letter of 28 October, and it was nice to hear from you again.

It is my understanding that the subject of magnetite is one which is being considered by the ISO along with all the other aspects relating to Coal Preparation. At some time in the future there will be therefore an International Standard.

The NCB too has been bringing together all our knowledge on requirements for magnetite supply, we have now reached second draft stage. A copy of this is enclosed and I trust that it may provide answers to some of your questions.

Kind regards.

Yours sincerely

P Cammack
Deputy Chief Coal Preparation Engineer
Coal Preparation Division

praxis

Praxis Engineers, Inc.

November 12, 1985

Mr. D.G. Osborne
Senior Coal Preparation Engineer
Kilborn Engineering (B.C.) Ltd.
1380 Burrard Street
Vancouver, Canada V6Z 2B7

SUBJECT: Your inquiry re Magnetite Test Standards

Dear Doug:

Thank you for your letter dated October 28, 1985. As the letterhead indicates, I no longer work at EPRI, and have not done so since 1982.

I do not know of any test procedures that have been standardized on an industry-wide basis in the U.S.. The three tests that are normally conducted are:

- o Non-magnetics content
- o Size analysis
- o Specific gravity

Part of the reason for our indifference to the characteristics of magnetite lies in the fact that the U.S. coals are not very friable, and in most cases, contain little near-gravity material at the desired quality levels. If you need further information on the American practices, the best person to contact is:

Mr. Al Deurbrouck
U.S. Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, Pennsylvania 15236
(412) 675 5706

If I can be of any further assistance, please let me know. Please convey my regards to Gerard Laman.

Sincerely,

Randhir Sehgal
President

cc: A. Deurbrouck, DOE

175 Dempsey Road, Suite 177, Milpitas, California 95035 (408) 945-4282

CSIR

Council for Scientific and Industrial Research

National Institute for Coal Research

P O Box 217 Pretoria 0001 South Africa ● Tel. National (012) 48-6020
Telex 3-0430 SA Telegrams Furesbo International + 27 12 48-6020

Our ref. EFEM/je 22 Your ref.

NEW/NUWE: TEL. NO. (012) 342-1020
TELEX NO. TELEKSNO. 3-20430 SA

13 November 1985

Dr D G Osborne
Senior Coal Preparation Engineer
Kilborn Engineering (B.C.) Ltd
1380 Burrard St
Vancouver BC
V6Z 2B7
CANADA

Dear Dave

Thank you for your letter dated 28 October 1985, regarding magnetite testing.

First of all I would like to point out that the Fuel Research Institute was incorporated into the CSIR and is now known as the National Institute for Coal Research. The address, and functions in the main, remain as they were.

Regarding the enquiries about magnetite testing, I can point out that ISO has a working group preparing a standard "The Testing of Magnetite for use in Coal Preparation". A second draft proposed was recently submitted for ballot and this Institute, through the SABS, voted in favour of it. You could probably acquire a copy from the secretariat, which is in Australia.

Document ISO/TC27/SC1 N222E
Standards Association Australia
P O Box 458
North Sydney
NSW 2060
AUSTRALIA TELEX: 26514 ASTAM

Canada is also a participating member of ISO/TC27 on solid mineral fuels, so you might obtain the documentation from there.

2/ ...

In addition, MINTEK produced a report on procedures for the evaluation of magnetite which should be suitable for your purpose. The title is:

> Report No. M144 "The Development of Standard Procedures for the Evaluation of Magnetite for Use in Heavy Medium Separation", L Jonker (30th May 1984).

The address, in case you do not have it, is:

Council for Mineral Technology
Private Bag X3015
RANDBURG
2125
SOUTH AFRICA

Unfortunately we cannot supply you with a copy. However, I will send MINTEK a copy of your letter and of our reply, and request them to forward to you a copy of Report M144. This could save time.

Regarding our own normal analytical procedures, we tend to do the following on a more regular basis:

(i) Magnetic contents - Davis tube.

(ii) Size grading - Cyclosizer.

Wet sieving is possible to a minimum size of 45 microns. But as the greater portion of the magnetite is less than 45 microns, we use the cyclosizer.

(iii) Density - Hydrogen Pycnometer.

The relative density bottle method is suitable, provided the necessary precautions are taken.

(iv) Settling rate - This is sometimes carried out using the F5 method.

At present, we are also investigating other methods of determining settling rates, and also viscosity. Little information is available at this stage so no further comments can be made.

I hope that I will be able to attend the 10th ICPC. If this is possible, I will most certainly make use of your offer to make arrangements.

With kind regards.

Yours sincerely

EWALD MüLLER

CSIR

Council for Scientific and Industrial Research

National Institute for Coal Research

P O Box 217 Pretoria 0001 South Africa • Tel. National (012) 48-6020
Telex 3-0430 SA Telegrams Furesbo International + 27 12 48-6020

NEW NUWE: TEL. NO. (012) 342-1020
TELEX NO.
TELEKSNO. 3-20430 SA

Our ref. EFEM/je 22 Your ref.

ENQUIRIES : MR E F E MÜLLER

13 November 1985

The Secretary
MINTEK
Private Bag X3015
RANDBURG
2125

Dear Sir

KILBORN ENGINEERING IN CANADA : ENQUIRIES RE MAGNETITE

The NICR received a request from a Dr D G Osborne of Kilborn Engineering in Canada regarding the testing of magnetite.

His attention has been drawn to a Mintek report:

M144 : The Development of Standard Procedures for the Evaluation of Magnetite for Use in Heavy Medium Separation.

We stated that we would approach you to send him a copy of this report, and therefore request you to forward a copy to:

Dr D G Osborne
Senior Coal Preparation Engineer
Kilborn Engineering (B.C.) Ltd
1380 Burrard St
Vancouver BC
V6Z 2B7
CANADA

For your information, copies of Dr Osborne's letter and our reply are attached.

Yours faithfully

E.F.E. Müller

for: CHIEF DIRECTOR

MINTEK

REPORT

No. M144

THE DEVELOPMENT OF STANDARD PROCEDURES FOR THE EVALUATION OF MAGNETITE FOR USE IN HEAVY-MEDIUM SEPARATION

by

L. Jonker

30th May, 1984

COUNCIL FOR MINERAL TECHNOLOGY
200 Hans Strijdom Road
RANDBURG
South Africa

Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, Pennsylvania 15236-0940

November 18, 1985

Mr. D. G. Osborne
Kilborn Engineering (B.C.) Ltd.
1380 Burrard Street
Vancouver, Canada V6Z 2B7

Dear Dave,

As per our phone conversation, I am sending you several articles on the testing and use of magnetite, including:

1. Reiss-Viking Davis Tube Procedure.
2. Davis Tube Paper by N. Schultz.
3. Standard Procedures for Magnetite Evaluation by MINTEK, S. Africa.
4. Recent ISO Draft Proposal 8833, "The Testing of Magnetite for Use in Coal Prep."
5. My comments to Ron Morlock on DP8833.
6. Two procedures used at the Homer City Lab.
7. "Coal Preparation - Dense Media Rheology, A Review of Measurement and Control," by C. C. Graham and R. Lamb, ACIRL Coal Research.
8. United States Patent 4,432,868, "Separation of High Grade Magnetite from Fly Ash."
9. Magnetite Fact Sheet.
10. DOE/ET/13014-T1, "Heavy Medium Recovery in Coal Washing by Continuous High Gradient Magnetic Separation," by David R. Kelland, Massachusetts Institute of Technology.
11. IS-4839, "Characterization and Performance Evaluation of Fly Ash-Derived Heavy-Medium Material," by D. Birlingmair et al., Iowa State University.

I hope you will find them helpful. We look forward to receiving the summary report that you and CANMET put together.

Sincerely,

Rich Killmeyer

Richard P. Killmeyer
Supervisory Chemical Engineer
Coal Preparation Division

Enclosures

DOE/ET/13014-T1
(DE85005606)

HEAVY MEDIUM RECOVERY IN COAL WASHING BY CONTINUOUS HIGH GRADIENT MAGNETIC SEPARATION

Final Report

By
David R. Kelland

September 1983

Work Performed Under Contract No. AT01-76ET13014

For
U. S. Department of Energy
Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania

By
Massachusetts Institute of Technology
Francis Bitter National Magnet Laboratory
Cambridge, Massachusetts

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

Energy

FOSSIL

IS-4839
(DE84001858)

CHARACTERIZATION AND PERFORMANCE EVALUATION OF FLY ASH-DERIVED HEAVY-MEDIUM MATERIAL

Final Report

By
D. Birlingmair
M. Murtha
R. Killmeyer

March 31, 1983
Date Transmitted

Work Performed Under Contract No. W-7405-ENG-82

Iowa State University
Ames Laboratory
Ames, Iowa

TECHNICAL INFORMATION CENTER
U. S. DEPARTMENT OF ENERGY

Stamicarbon bv
The licensing subsidiary of DSM

Kilborn Engineering
1380 Burrard St.
VANCOUVER
Canada V6Z 2B7
Attn. Mr. D.G. Osborne

your letter of	your reference	our reference	Geleen,
		21570 Stac/95-17	December 19, 1985

Dear Mr. Osborne,

With reference to your letter of November 20, 1985 please find enclosed our Memo 19938 entitled:

"Evaluation of Analytical Techniques for Determination of the Grain-size Distribution of Solid Particles in Heavy Media".

We wish you every success for the magnetite project and would appreciate hearing about the results in due course.

We hope you have meanwhile received our wishes for the coming festive season by separate mail.

Yours faithfully,

STAMICARBON BV

H.F. Jennekens
Senior Project Engineer, Mineral Beneficiation

RECEIVED
Ans'd

Enclosures: 1

RECEIVED

JAN 21 1986

Ans'd.

Central Research Laboratories
Shortland, NSW 2307
All communications to Director
PO Box 188, Wallsend
NSW, Australia 2287
Telephone 049 51 2444
Telex AA28766
Facsimile 049 513 740

BHP
Research &
New Technology

8 January 1986

PERSONAL

Dr D G Osborne
Senior Coal Preparation Engineer
Kilborn Engineering (BC) Ltd
1380 Burrard Street
VANCOUVER CANADA V6Z 2B7

Dear David

Stuart Nicol passed your letter regarding magnetite quality on to me, and I apologise for the long delay in replying. At the outset I regret to say that Australia is in a similar position to Canada in that an official standard for the testing and evaluation of magnetites does not exist. A standard is in preparation, but as yet no draft has been produced for comment. Thus, all I can do is give you my personal view of the situation within the Australian coal industry.

At present, there is effectively only one supplier of magnetite to the Australian Coal Industry. This supplier provides five grades of material based of the following size analysis, with price increasing with fineness.

Grade	Percent Passing 53 micron
Coarse	50-60%
Medium	65-75%
Fine	85-90%
Superfine	92-95%
Super Superfine or Ultrafine	94-97%

Due to medium stability problems, the superfine and ultrafine grades comprise by far the majority of sales. The supplier has only one deposit and the different grades are produced by altering the operation of the supplier's product ball mill. As you appreciate, the majority of magnetite testing in Australia is thus devoted solely to magnetite size analysis in order to determine whether the supplied magnetite is of the specified fineness.

The other general magnetite specifications are:

Specific gravity	4.9 minimum
Magnetic content (Davis tube 700 gauss)	96%

and typical chemical analyses are:

SiO_2	1.4%
Al_2O_3	0.8%
Total Fe	69.5%
Fe_3O_4	95.0%
S	0.4%
P	0.02%
Cu	0.005%
H_2O (110°C)	10% max

Despite the virtual control of the magnetite market by one supplier, a number of companies, including some with South African sources, have been attempting to enter the market. We have had some samples delivered to us for evaluation and the tests we subject the sample to are as follows:

1 Specific gravity determination - minimum acceptable value is 4.90.

2 Chemical analysis for Al_2O_3, Cao, CuO, Total Fe, Fe^{2+}, K_2O, Mn, NiO, P_2O_5, S, SiO_2, TiO_2, V_2O_5, Zno and total moisture.

3 Mineralogical examination.

4 Size analysis via combination of sieves down to 38 microns and cyclosizer below 38 microns.

5 Recoverable magnetics - Davis tube at 400, 550 and 700 gauss. Minimum acceptable magnetics is 96% at 700 gauss, but recovery should not be particularly dependent on field strength.

6 Settling rate measurement - the settling rate of magnetite from a slurry magnetite concentration of 500g/litre (corresponding to slurry relative density of approx. 1.40) in a measuring cylinder is determined. This test is carried out on an 'as received' sample and a sample demagnetised by passing it through an AC coil. Generally a superfine grade magnetite has a settling rate of about 2.5cm/min. The demagnetised sample is used as a check for the presence of any 'flocs' or 'stringers' of magnetite. If there is a large discrepancy between the setting rates of the 'as received' and 'demagnetised' samples, tests on the magnetic qualities of the material may be undertaken. These tests cannot be done on-site but require fairly simple magnetic equipment. The properties measured and their acceptable values are:

Initial Susceptibility, K_{30} (emu/g)	> 0.050
Susceptibility at 800 oersteds, K_{800} (emu/g)	> 0.053
Saturation moment, M_{sat} (emu/g)	> 80
Coercive force, H_c (oersteds)	< 50

Of these four, the one which we look at most closely is the coercive force. This is approximately linearly dependent upon magnetic remanence. A high coervice force usually correlates with a high-settling rate of the 'as received' material, and is commonly caused by a high level of titania. Magnetites with titania contents above 1%, are prone to agglomeration and this can cause medium stability problems in washeries not fitted with AC demagnetising coils.

I hope the above comments have been of some use. We would be happy to provide you with any further details you may require.

Yours faithfully

Col Bensley

Colin Bensley
Senior Research Officer

rpc

research and productivity council
conseil de recherche et de productivité

RECEIVE
[illegible] 17 19
Ans'd

January 13, 1986

Dr. David Osborne
Kilborn Engineering Ltd.
1380 Burrad Street
Vancouver, B.C.
V6Z 2B7

Dear Dr. Osborne:

Magdi Mikhail of the CANMET coal research laboratory, Edmonton has telephoned to enquire about our work on using a magnetic concentrate from Minto fly ash for heavy media.

The CANMET contract has not yet been issued but it should be soon. As a result no further work has yet been done. Attached is a report on the preliminary work we did in 1983.

I will be happy to be of assistance in your project.

Yours truly,

D. Abbott
Head, Philip Salib

/ja
encl
cc: M. Mikhail, CANMET, Edmonton

P.O. Box 6000, Fredericton, New Brunswick, Canada E3B 5H1 • Telephone 506 452-8994 • Telex 014-46115 • Cable Reprodco – Frederic

PREPARATION OF A HIGH SPECIFIC GRAVITY CONCENTRATE FROM THE IRON-RICH FLY ASH OF THE MINTO COAL, NEW BRUNSWICK

Work Commissioned by

J.L. Williamson, Deputy Minister
NEW BRUNSWICK ENERGY SECRETARIAT

Job 50195/1
Report AS/84/21
November 10, 1983

D. Abbott
Manager, Energy Projects

STEINKOHLENBERGBAUVEREIN

Steinkohlenbergbauverein · Postfach 130140 · 4300 Essen 13

Dr.-Ing. D. Leininger

D.G Osborne, P.Eng.
Senior Coal Prep.Eng.
Kilborn Engineering(B.C.)Ltd.

1380 Burrard St.

Vancouver / Canada V6Z 2B7

RECEIVED
FEB [illegible]
Ans'd.

Ihre Zeichen	Ihre Nachricht vom	Unsere Zeichen	Unser Hausruf	Franz-Fischer-Weg 61 **Essen-Kray**
	28. Okt. 85	K 2/ Lg/Pö	9 592 (Durchwahl)	29.1.1986

Lieber Dave!

Leider komme ich erst heute dazu, Ihren Brief vom 28.10.1985 zu beantworten. Er traf sehr verspätet hier ein.

Anliegend sende ich Ihnen einen Sonderdruck über

> "Eigenschaftsmerkmale von Magnetit als Schwerstoff
> für die Schwertrübesortierung von Steinkohlen".

Ich hoffe, daß wir Ihrer Nachfrage entsprechen konnten und verbleibe

mit freundlichem Gruß und Glückauf!

Ihr

Leininger

Eigenschaftsmerkmale von Magnetit als Schwerstoff für die Schwertrübesortierung von Steinkohlen

Characteristic properties of magnetite as a high-gravity solid for the heavy-medium separation of coal

Les caractéristiques de la magnétite employée comme matière lourde dans la séparation de la houille par liquide dense

Características de la magnetita empleada como materia pesada en la preparación de la hulla por medio denso

Dipl.-Ing. A. Müller, Saarbrücken

Zusammenfassung

Es wird die Untersuchungsmethode zur Bestimmung des Absetzverhaltens von Magnetiten beschrieben, um für die Schwertrübesortierung von Steinkohlen die richtige Auswahl treffen zu können. Bei unbekannten oder neuen Magnetiten ist neben der Kenntnis der Stoffeigenschaften wie Korngrößenverteilung, Dichte, magnetische Reinheit auch die Kenntnis des Absetzverhaltens der Magnetittrübe von großer Bedeutung.

Auch hat sich erwiesen, daß Magnetit mit höheren Schwefelgehalten zur Verklumpung neigen kann und damit als Schwerstoff zur Herstellung von Schwertrüben nicht mehr verwendbar ist. Um Versorgungsschwierigkeiten auszuschließen, sollte ein Eigenschaftsmerkmal hierfür vorhanden sein. Erfahrungen mit Magnetit machen auf diese Forderung aufmerksam.

Résumé

L'auteur décrit une méthode d'essais permettant de déterminer le comportement à la décantation des magnétites, afin de pouvoir en faire un choix correct lorsqu'il s'agit de la séparation de houille par liquide dense. Dans le cas des magnétites inconnues ou nouvelles, il est très important de connaitre non seulement les caractéristiques de la matière, telles que la distribution granulométrique, la densité et la pureté magnétique, mais également le comportement à la décantation de la pulpe de magnétite.

Il s'est avéré également que la magnétite contenant des pourcentages de soufre plus élevés peut avoir tendance à former des grumeaux, ce qui ne permettrait plus de l'utiliser comme matière lourde pour la préparation de liquides denses. Afin d'exclure des difficultés d'approvisionnement, on devrait disposer d'une caractéristique à ce sujet. Les expériences acquises avec la magnétite nous montrent cette nécessité.

Resumen

Se describe un método de ensayo que permite determinar el comportamiento a la decantación de las magnetitas, con el fin de poder hacer una correcta elección de las mismas para la separación de la hulla por medio denso. En el caso de las magnetitas desconocidas o nuevas, es de gran importancia conocer el comportamiento a la decantación de la pulpa de magnetita, aparte de las características del material, tales como distribución granulométrica, densidad y pureza magnética.

Summary

A method for the determination of the settling behaviour of magnetites is described with a view to making the correct choice for heavy-medium separation of coal. With unknown or new magnetites it is important not only to know the material properties such as particle size distribution, density and magnetic purity, but also the settling behaviour of the magnetite medium. It has also been found that magnetite with a relatively high sulphur content may tend to form lumps and thus become unsuitable for making heavy media. In order to obviate difficulties in obtaining appropriate supplies, a characteristic property to serve as a criterion for this should be available. Experience with magnetite is reported which draws attention to the relevance of this requirement.

Development of a method for investigating the settling behaviour of magnetite

General

Every material used in coal preparation must more particularly satisfy requirements as to its properties and effectiveness. It is necessary to have suitable methods of testing in order to obtain information on what properties and effects are required, e. g., for optimizing a material, and furthermore in order to verify compliance with these requirements, e. g., as to type conformity of consignments supplied. For this reason FABERG, Essen, the Standardization Committee on Mining Engineering within the German Standards Institution (DIN) is engaged in preparing appropriate standards for process operating materials and the testing thereof. The method for determining the quality characteristic "settling behaviour of a heavy medium" described in this article has been developed by Saarbergwerke AG and is intended as a contribution to the drafting of the Standard "Heavy media; definitions, requirements and testing". As magnetite is virtually the only high-gravity material used in coal preparation in the Federal Republic of Germany, the test method is based on magnetite.

Viscosity

The heavy-medium (or dense-medium) separation process is considerably affected not only by the properties of the raw material, but also by that of the magnetite employed. The density of the medium, the separation density and also to a high degree the viscosity of the magnetite medium have a

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

Department of Mineral Resources Engineering.
Royal School of Mines. London SW7 2BP.
Telephone: 01-589 5111 Ext: . Telex 261503.

22nd January 1986

Dr D.G. Osborne
Kilborn Engineering Ltd.
1380 Burraro Street
Vancouver
Canada V6Z 2B7

Dear Dave

At last I have managed to search out the references of Tim Napier-Munns work on FeSi, a list is attached. I understand he is continuing some aspects of this in Australia, while also promoting the Debex Viscosity and stability meters for DMS plants. (On-line viscosity and stability measurements in coal prep plants: any use?)

My life continues much as ever with teaching and consulting work dominating but money in U.K. universities is in short supply for study tours, hence no change of overseas visits in the foreseable future. Mind you Lado has arranged one of his courses in Holland so at least I will get to cross the Channel!

Hope to see you in the not too distant future.

Regards.

Rod.

R. Gochin

T. Napier-Munn

1. a) Density inversion in dense medium cyclones
   b) Residence time of mineral particles in dense medium cyclones.

   both in Trans. I.M.M., 94 (1985) C96 - C101

2. Use of density tracers for determination of the Tromp curve for gravity separation processes.

   Trans. I.M.M., 94 (1985) C47 - C54

3. Design and operation of dense medium cyclone plants

   J.S. Afr. I.M.M., December 1974, 120 - 133

4. A mechanism of separation in dense medium cyclones. Paper G2

   Proc. 2nd Int. Conf. on Hydrocyclones, Bath U.K., Sept. 1984, Pub. by BHRA, Cranfield, Beds.

5. The monitoring of medium rheology in DMS plants.

   Proc. 2nd Samancor Symp. Perth, Australia, July 1985 Pub. by Samancor in S. Africa.

6. Influence of medium viscosity on the density separation of minerals in cyclones, P63 - 82

   Proc. 1st Int. Conf. on Hydrocyclones, Cambridge, U.K. October 1980, BHRA, Cramfield.

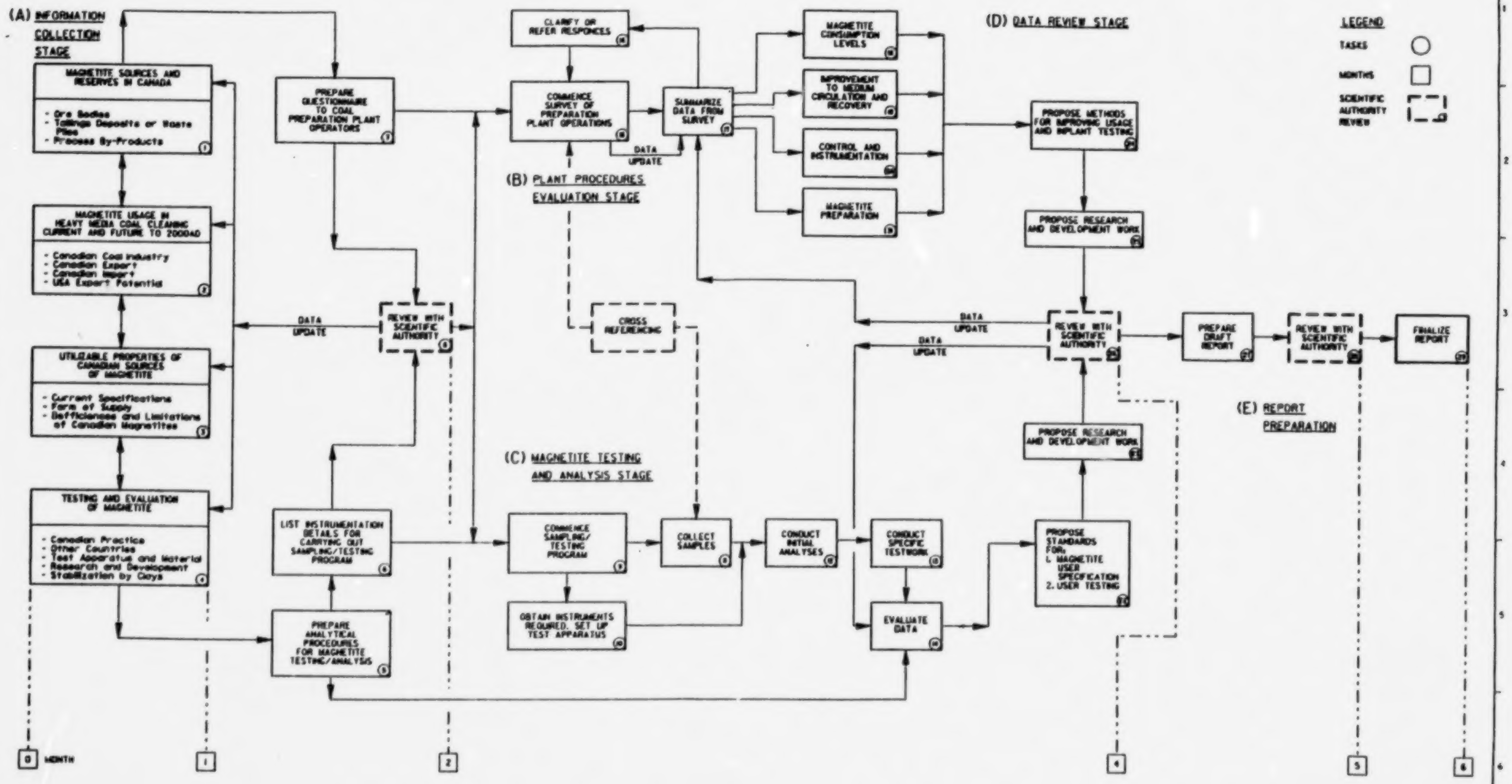
Other DMS papers:

1. A study of the Dynawhirlpool. Hacioglu, E. and Turner, J. Proc. 15th Int. Min. Proc. Cong., Cannes, 1985.
2. The introduction of process control to coal preparation. Corbridge, C., Colliery Guardian, June 1984, 221 - 222.
3. Coal Preparation - dense media rheology, Graham, C. and Lamb R. Publ. PR 82-3. Australian Coal Industry Research Labs. April 1982, (from P.O. Box 83, North Ryde, N.S.W. 2113).
4. Coal Preparation, Kelly E. and Spottiswood, D., Color School of Mines, Min. and Energy Resources 26(1983) No. 3.

Nothing in the U.K. press of note.

APPENDIX 'B'

COMMUNICATIONS WITH EDMONTON COAL RESEARCH LABORATORY


(A) INFORMATION COLLECTION STAGE
MAGNETITE SOURCES AND RESERVES IN CANADA
- Ore Bodies
- Tailings Deposits or Waste Piles
- Process By-Products
MAGNETITE USAGE IN HEAVY MEDIA COAL CLEANING CURRENT AND FUTURE TO 2000AD
- Canadian Coal Industry
- Canadian Export
- Canadian Import
- USA Export Potential
UTILIZABLE PROPERTIES OF CANADIAN SOURCES OF MAGNETITE
- Current Specifications
- Form of Supply
- Defficiencies and Limitations of Canadian Magnetites
TESTING AND EVALUATION OF MAGNETITE
- Canadian Practice
- Other Countries
- Test Apparatus and Material
- Research and Development
- Stabilization by Clays
PREPARE QUESTIONNAIRE TO COAL PREPARATION PLANT OPERATORS
DATA UPDATE
REVIEW WITH SCIENTIFIC AUTHORITY
LIST INSTRUMENTATION DETAILS FOR CARRYING OUT SAMPLING/TESTING PROGRAM
PREPARE ANALYTICAL PROCEDURES FOR MAGNETITE TESTING/ANALYSIS
CLARIFY OR REFER RESPONCES
COMMENCE SURVEY OF PREPARATION PLANT OPERATIONS
DATA UPDATE
SUMMARIZE DATA FROM SURVEY
(B) PLANT PROCEDURES EVALUATION STAGE
CROSS REFERENCING
(C) MAGNETITE TESTING AND ANALYSIS STAGE
COMMENCE SAMPLING/ TESTING PROGRAM
OBTAIN INSTRUMENTS REQUIRED. SET UP TEST APPARATUS
COLLECT SAMPLES
CONDUCT INITIAL ANALYSES
CONDUCT SPECIFIC TESTWORK
EVALUATE DATA
MAGNETITE CONSUMPTION LEVELS
IMPROVEMENT TO MEDIUM CIRCULATION AND RECOVERY
CONTROL AND INSTRUMENTATION
MAGNETITE PREPARATION
(D) DATA REVIEW STAGE
PROPOSE METHODS FOR IMPROVING USAGE AND INPLANT TESTING
PROPOSE RESEARCH AND DEVELOPMENT WORK
DATA UPDATE
DATA UPDATE
REVIEW WITH SCIENTIFIC AUTHORITY
PROPOSE RESEARCH AND DEVELOPMENT WORK
PROPOSE STANDARDS FOR: 1. MAGNETITE USER SPECIFICATION 2. USER TESTING
PREPARE DRAFT REPORT
REVIEW WITH SCIENTIFIC AUTHORITY
FINALIZE REPORT
(E) REPORT PREPARATION
LEGEND
TASKS
MONTHS
SCIENTIFIC AUTHORITY REVIEW
0 MONTH
1
2
4
5
6

CLIENT: SUPPLY AND SERVICES, CANADA
LOCATION: COAL RESEARCH LAB., EMR., CANMET

KILBORN

TITLE
ACTIVITIES FLOWCHART FOR DETERMINATION OF CHARACTERISTICS OF CANADIAN MAGNETITE RESOURCES FOR OPTIMUM UTILIZATION IN COAL HEAVY MEDIA PROCESSES

REFERENCE DRAWINGS

REVISIONS

REVISIONS

KILBORN

Kilborn Engineering (B.C.) Ltd. / 1380 Burrard St., Vancouver, Canada V6Z 2B7
Telex: 04-507734, Tel: (604) 669-8811

November 22, 1985

Energy Mines and Resources
CANMET
Coal Research Laboratories
P. O. Bag 1280
Devon, Alberta
TOC 1E0

Attention: Mr. M. W. Mikhail
Head, Coal Preparation Section

Dear Magdy:

Re: Magnetite Study
DSS File No. 03SQ.23440-4-9229

As a follow-up to our recent visit to your office, I am enclosing one (1) copy of the Questionnaire concerning Canadian magnetite use in the coal mines.

It is our understanding that you will review the questions, and will send out the enquiry to the Canadian Coal Mines in the next few weeks.

If you have any questions regarding the Questionnaire, please contact us.

Dave Osborne will be reviewing this with you on his visit on December 12th and 13th.

I wish to thank you for your hospitality while at the plant, and look forward to seeing you in Vancouver in the near future.

Yours very truly,

KILBORN ENGINEERING (B. C.) LTD.

R Davies

R. J. Davies, P.Eng.
Project Manager

RJD/mr
Enclosure

cc: D. G. Osborne

CHARACTERISTICS OF CANADIAN MAGNETITE
RESOURCES FOR OPTIMUM UTILIZATION
IN COAL MEDIUM PROCESSES

QUESTIONNAIRE

Magnetite Supplier(s): ______________________________
(Name and Address)
____
____
____
____

Cost Per Tonne Delivered to Mine Site: ____________________
(or other basis)
____

Quotations From Other Potential Suppliers:

Name	Cost

Method of Storage and Handling (include a simple flowsheet, if possible):

____
____
____
____

Storage Capacity at Plant Site: ____________________ Tonnes

Minimum Inventory Required: ____________________ Tonnes

Annual Magnetite Consumption: ____________________ Tonnes

Specification of Supplied Magnetite:

Percent Magnetics Content, greater than: ____________ %
Percent Iron Content: ____________ %
Percent Minus 45 Microns (325 Mesh): ____________ %
Percent Total Moisture: ____________ %
Percent Non-Magnetics: ____________ %
Density: ____________
Other Characteristics: ____________

Number of Shipments Per Annum: ____________

Method of Transportation: ____________

____

Mode of Supply (Bulk, Bag, etc.): ____________

Number of Quality Tests Per Annum: ____________

Quality Analysis in Plant and/or
Outside (Commercial) Laboratory: ____________

____

Type of Test Used for Plant Quality Analysis:

Sizing: ____________

Method and Sieve Sizes: ____________

____

____

Magnetic Content: ____________

Method: ____________

____

____

Percent Total Moisture: ____________ %

Method: ____________

____

____

Density: ____________________

Method: ____________________

____

____

Settling Rate (Stability): ____________________

Method: ____________________

____

____

Ease of Demagnetization: ____________________

Method: ____________________

____

____

Is Sample Demagnetized Before Size Analysis?: ____________________

Is Medium in Preparation Plant Tested for Settling, Method?: ____________________

Number of Tests Per Month: ____________________

General Comments Regarding Quality:

____

____

____

____

____

Type of Analysis for Outside Performed Quality Tests:

Sizing, Number of Sieves Reported: ____________________

____

Magnetic Content: ____________________

Fe Content: ____________

Percent Total Moisture: ____________ %

Percent Non-Magnetics: ____________ %

Density: ____________

Settling Rate: ____________

Ease of Demagnetization: ____________

Other(s): ____________

Is Magnetite Milled at Plant Site?: ____________

Size Consist of Milled Magnetite: ____________

Describe Milling Circuit (include simple flowsheet, if available):

Describe Magnetite Recovery Circuit (include simple flowsheet, if available):

Is there any new equipment under test in your plant in Magnetite Circuits, e.g., Pumps, Magnetic Separators, Instrumentation, Control Devices, Samplers, etc.?:

	Size	Quantity	Manufacturer
Primary Mag. Sep.:			
Secondary Mag. Sep.:			
Scavenger Mag. Sep.:			
Dilute Med. Cyclone:			

Describe General Preparation Process, indicate on enclosed Flowsheet Process Changes:

Dense Medium Circuit Feed Rate ____________________ Tonne/Hour
(Air Dry Basis, or other)

Magnetite Consumption per tonne of feed to the Dense Medium Circuits:

Describe Method(s) Used to Determine Magnetite Consumption:

Where do you think greatest Magnetite Loss is encountered at present?:

Any plans to cut Losses?:

If a Scavenger Magnetic Separator installed, describe Type and Location:

Type:

Location:

Volume

2

EMR: CANMET

EDMONTON COAL RESEARCH LABORATORY

KILBORN PROJECT NO. 7814-15

CHARACTERISTICS OF CANADIAN MAGNETITE RESOURCES FOR OPTIMUM UTILIZATION IN COAL HEAVY MEDIA PROCESSES

REPORT ON

PLANT PROCEDURES AND MAGNETITE TESTING AND ANALYSIS

172pp

SUBMITTED BY:

KILBORN ENGINEERING (B.C.) LTD.
1380 Burrard Street
Vancouver, B.C.
V6Z 2B7

MARCH, 1986

MICROMEDIA

KILBORN

Kilborn Engineering (B.C.) Ltd., Suite 400 - 1380 Burrard Street, Vancouver, B.C., Canada V6Z 2B7
Telex: 04-507734, Telephone: (604) 669-8811, Facsimile: (604) 669-0847

March 27, 1986

Edmonton Coal Research Laboratory
CANMET
One Oil Patch Drive
Devon, Alberta
TOC 1E0

Attention: Mr. M.W. Mikhail
Project Scientific Authority

Dear Sirs:

Please find enclosed ten (10) copies of the Final Report for the Project:

'CHARACTERISTICS OF CANADIAN MAGNETITE RESOURCES FOR OPTIMUM UTILIZATION IN COAL HEAVY MEDIA PROCESSES'.

This report includes:

Part I - 'Survey of Magnetic Medium Usage in Heavy Media Coal Cleaning' first submitted in February, 1986, and

Part II - 'Plant Procedures and Magnetite Testing and Analysis' containing the concluding sections of the Project. Part II is divided into two sections:

(a) Plant Procedures Evaluation
(b) Magnetite Testing and Analysis.

We trust that this Report meets with your satisfaction and look forward to future opportunities to work with the Edmonton Coal Research Laboratory.

Yours truly,

KILBORN ENGINEERING (B.C.) LTD.

for R.J. Davies, P.Eng.
Project Manager

DGO/rlk
Enclosure

EMR: CANMET

EDMONTON COAL RESEARCH LABORATORY

KILBORN PROJECT NO. 7814-15

CHARACTERISTICS OF CANADIAN MAGNETITE RESOURCES FOR OPTIMUM UTILIZATION IN COAL HEAVY MEDIA PROCESSES

REPORT ON

PLANT PROCEDURES AND MAGNETITE TESTING AND ANALYSIS

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'A' TEST AND ANALYTICAL RESULTS OF CHEMEX LABS LTD.

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'C' SIZE DISTRIBUTION DATA OF EDMONTON COAL RESEARCH LABORATORY

'D' STABILITY INDEX TEST METHOD

'E' QUESTIONNAIRE

'F' ACTIVITIES FLOWCHART FOR THE PROJECT

1.0 INTRODUCTION

1.0 INTRODUCTION

Kilborn Engineering (B.C.) Ltd. (Kilborn) has been contracted to conduct a project to investigate the Characteristics of Canadian Magnetite Resources for Optimum Utilization in Coal Heavy Media Processes. The project has been divided into three working stages as follows:

(a) Information Collection
(b) Plant Procedures Evaluation
(c) Magnetite Testing and Analysis

The Project reporting is in two parts:

PART I which was issued on February 11, 1986, contains a Survey of Magnetite Medium Usage in Heavy Media Coal Cleaning.

PART II which follows this introduction, contains the description of the second and third working stages, ie. Plant Procedures and Magnetite Testing and Analysis together with a Summary of the total project.

Work on the plant procedures evaluation stage was preceded by the issue of a questionnaire concerning Canadian magnetite use in coal preparation plants as part of the first stage of the Project. This questionnaire was circulated to all Canadian plants that currently employ heavy media separations and also an American heavy media plant. Response was good and eight completed questionnaires were received which were subsequently used for the determination of Canadian practice in the use and testing of magnetite as a heavy medium.

Work on the magnetite testing and analysis stage was preceded by sample procurement from various sources of supply including several current suppliers of heavy media grade magnetite. Again, the response was good and ten sets of samples were obtained of which six were selected for a comprehensive test program. These samples emanated from three heavy media grade magnetite suppliers, two high grade magnetite 'tailings' deposits, and one placer deposit. Of these, two of the sources of supply have substantial mineable reserves of magnetite containing ore.

Chemex Labs Ltd. (Chemex) of Vancouver, a reknowned metallurgical analytical company, was contracted by Kilborn to perform the detailed test and analytical program on the six samples. Chemex in turn subcontracted specialized analysis of magnetic properties to the Australian Coal Industry Research Laboratories (A.C.I.R.L.) of N.S.W. Recent research and development work by A.C.I.R.L., supported by the Australian coal industry, has put them at the forefront of this field.

The outcome of the test and analytical program was principally intended to provide the following:

(a) Confirmation that the current draft ISO standard DP 8833 is applicable to Canadian practice;
(b) Routine methods for testing magnetite for heavy media application in Canadian coal preparation plants.

Part II of the final report on the Project therefore contains full details of the two final working stages of the project together with an overall summary of the project and recommendations for subsequent research and development work in the fields of:

(a) heavy media circuit design;
(b) magnetite loss control;
(c) rheological properties of magnetite medium.

2.0 SUMMARY

2.0 SUMMARY

2.1 MAGNETITE RESOURCES IN CANADA

Canada has plentiful deposits of useable magnetite, many of which are located in reasonably close proximity to the coal fields. It is, therefore, most unlikely that user companies will need to consider the alternative of long-term importation even in eastern Canadian coal fields. The current situation in western Canada, whereby much of the magnetite originates from one source, is unlikely to be perpetuated for much longer. The magnetite reserves of this producer limit its capability to supply on a long-term basis and other sources of supply will eventually appear as the selling price becomes more favourable to the supplier. At present, heavy media grade magnetite is available directly from stockpile and production costs are very low. Within the next few years, as existing stocks become depleted, production cost increases will undoubtedly cause the selling price to rise to cover the cost of mining, crushing, milling and beneficiation, especially for sources with potentially low transportation costs.

2.2 CANADIAN PRACTICE IN HEAVY MEDIA COAL CLEANING

Poor loss control rather than substandard magnetite quality would appear to be the principal cause of high magnetite consumption in many Canadian plants at the present time. Heavy loss appears to be the result of coal flow surges in the heavy media circuit created in most cases by poor raw coal blending and feeding or bad distribution to multi-stream circuits. In most cases, improvements could be made in the media distribution and recovery circuits which would result in reduction in loss but these are site specific to each plant and would require expert assistance in determining and monitoring loss control.

Based on the findings of the questionnaire survey, it would appear that realistic targets for magnetite consumption (loss) for Canadian coal preparation plants, other than those treating friable Rocky mountain coals, should be as follows:

Feed Size Range (mm)	Magnetite Consumption (kg per tonne feed to H.M. Circuit)
100 - 12	0.50
12 - 0.6	0.75

Treatment of Rocky Mountain coals, which generally contain between 25 0 40 percent, minus 0.6 millimetres in the raw coal, will result in higher losses because of the large amount of near-size material which these coals contain i.e. up to 7 percent, ± 0.1 millimetres at an aperture of separation of 0.6 millimetres. For these coals, magnetite consumption can be maintained at the following levels:

Feed Size Range (mm)	Magnetite Consumption (kg per tonne feed to H.M. Circuit)
100 - 12	0.75 - 1.00
12 - 0.6	1.00 - 1.50

Those plants which encounter abnormally large quantities of bentonitic clay content in the raw coal should be able to achieve, as working averages, targets lying between the two sets of values. Occasionally, higher levels of loss will occur unless the raw coal is homogenized by thorough blending.

2.3 CANADIAN PRACTICE IN MAGNETITE TESTING AND ANALYSIS

Few of Canada's plants are suitably equipped to carry out more than very basic analysis or testing of magnetite and much of the testing which is done is simplistic and non-quantitative when compared to practices in other major coal exporting countries, i.e., Australia and South Africa.

In broad terms, the generally accepted, preferred specification for heavy media grade magnetite is still that which was laid down many years ago by the National Coal Board (NCB) in Britain, i.e.:

(a) Relative density shall not be less than 4.85.
(b) Magnetic content shall not be less than 97 percent.
(c) The size fraction below 60 micron shall not be less than 85 percent by weight.
(d) The size fraction below 10 micron shall not exceed 25 percent by weight.
(e) Moisture content at the time of shipment shall not exceed 10 percent.
(f) Chemical composition shall in no way render it hazardous to operators, or unsuitable in any other way.

Items (a) to (d) are determined on a dry basis.

Most countries employ a specification similar to that of the NCB, but in some areas, especially where sources of supply are limited, e.g., in western Canada, some relaxation is tolerated in exchange for a favourable selling price.

The current Canadian practice as determined from the responses to the Questionnaire, is far less stringent than in other major coal export countries. Two of the plants surveyed do not carry out magnetite testing. The remainder tend to concentrate upon: size analysis at 325 mesh; checking magnetics content - usually with a Davis Tube; and determining moisture content. The number of times which these tests are carried out varies from 2 to 35 times per year.

Clearly, a tightening up on standards of acceptance in magnetite supplies and regular monitoring of circulating medium should result in worthwhile improvement in magnetite loss. Also, as tailings pond deposits of magnetite become depleted, thereby eliminating the only existing sources of the current low cost product, other suppliers will begin to produce superior heavy media grade products which will introduce a more competitive environment into the market. Kilborn believes that this will induce a determination on the part of suppliers to meet the required grade. At the same time it will encourage greater stringency on the part of the supplier.

2.4 THE NEW ISO STANDARD

Perhaps the most significant development in terms of the application of magnetite for heavy media coal cleaning has been the production of the draft ISO Standard, DP 8833, for the 'Testing of Magnetite for Use in Coal Preparation'.

With the emergence of this document as a firm standard later in 1986, there will be, for the first time, an internationally agreed approach to the identification of the essential requirements of a magnetite for use in heavy media coal cleaning. There will also be a definition of suitable methods for testing this material.

The tests specified in this International Standard will assist the user in the selection of magnetite and provide a basis for quality control testing. However, no attempt has been made to formulate the requirements for specific applications.

These specified tests will ensure that the properties which make magnetite suitable for heavy media coal cleaning purposes are effectively tested. These properties are:

(a) Moisture content, as received, percent;
(b) Particle size distribution, microns;
(c) Ferro magnetics content, percent;
(d) Relative density, grams per cubic centimetre;
(e) Total iron content, percent;
(f) Ferrous iron content;
(g) Fundamental magnetic properties.

All of these properties may require testing for the detailed assessment of a new source of magnetite, but for routine checking of regular supplies only, (a), (b), (c) and (d) should be necessary.

2.5 THE PROPOSED TEST AND ANALYTICAL APPROACH

Following review of analytical procedures and results, it was decided by Kilborn and Chemex that the preparation/analytical content for a Canadian code of practice should be as follows:

Density:	By the wet Pycnometer method
Magnetics Content:	By magnetic chute
Moisture Content:	By oven evaporation
Settling Test:	Using a glass tube apparatus
Size Analysis:	Using the method proposed in the ISO 8833 ie. wet sieves and centrifugal classifier
Total Iron and Ferrous Iron Content:	Using the method in the ISO 2597

The above determinations would normally be carried out with samples obtained from each consignment of magnetite delivered by a regular supplier. Analytical work recommended for new or potential sources of supply would comprise the folloiwng:

Magnetic properties - using the method described by A.C.I.R.L. to carry out measurement of:

Initial Susceptibility, (emu/g)
Susceptibility at 800 oersteds, (emu/g)
Saturation Moment, (emu/g)
Coercive Force, (oersteds)

Chemical analysis including $Si O_2$, Al_2O_3, $Ti O_2$, S, P, and Cu in addition to total iron and Fe_3O_4.

Mineralogical Examination
Viscometric Measurements

Because of the specialized nature of these tests it is suggested that they would be best undertaken by a research institute, university, or suitably qualified commercial laboratory rather than at the mine site.

2.6 FUTURE RESEARCH AND DEVELOPMENT WORK

Areas which should be further investigated as part of an on-going program of research and development in the field of coal heavy media separation may be sub-divided into:

a) Plant Operations, Media Recovery and Preparation
b) Magnetite Testing

Work in Plant Operations, Media Recovery and Preparation should include:

1. Testing new instrumentation/control equipment
2. Slurry pump testing
3. Testing magnetic separation equipment
4. Testing on-line analysis for particle size and non-magnetics content analysis
5. Pilot plant testing of fly-ash derived magnetic material

It is known that Edmonton Coal Research Laboratory is already planning to conduct research work into the cleaning of fine coal by heavy media cyclone and some of the above work could be incorporated into this program.

Work in magnetite testing should include:

1. Use of chemicals for media stabilization
2. Investigation of viscosity effects
3. Investigation of size distribution effects
4. Calibration methods for measuring devices
5. Development of field test/analysing equipment

3.0 PLANT PROCEDURES EVALUATION

3.0 PLANT PROCEDURE EVALUATION

3.1 MAGNETITE USER QUESTIONNAIRE

In order to determine current practice in Canadian coal preparation plants, a questionnaire was prepared and circulated to all Canadian plants which currently utilize heavy media separators and one American heavy media plant.

The questionnaire covered the following aspects:

(a) magnetite source(s) of supply and specification;
(b) methods of storage and handling at the plant site;
(c) annual consumption of magnetite;
(d) procedures for quality checks and for monitoring areas of magnetite loss in the heavy media circuits;
(e) basic details of the heavy media circuit(s);
(f) basic details of magnetite make-up and recovery circuits.

Of the twelve original recipients, eight had responded at the time of producing this report. Summary tables compiled from these responses are included at the end of this section. Reference is made to these results during the various subsections which follow.

3.2 MAGNETITE CONSUMPTION LEVELS

The consumption (and subsequent loss) of magnetite is governed by several factors, of which the most important are:

(a) The fineness of the magnetite - finely ground magnetite has process advantages in that it improves efficiency and therefore yield. However, it has a disadvantage that the finer particles are more susceptible to loss from the circuit.

(b) The fineness of the coal being treated - it is more difficult to remove magnetite from fine coal and refuse material than from coarse material.

(c) The efficiency of magnetic separators - there are numerous factors that effect efficiency - Gauss rating of the permanent magnets, the position of the permanent magnets, the feed volume to the separators, the percentage of magnetics in the feed to the separators, etc.

(d) The design of the magnetite recovery circuit - there are numerous design alternatives for magnetite circuits incorporating such variations as single vs. two-stage separators; countercurrent vs. concurrent rotation of separator drums, use of dilute medium cyclones vs magnetite thickeners; and need for secondary and even tertiary magnetite recovery systems.

The design of the magnetite recovery circuit should match the heavy media process being used and the gravity control system employed. Poorly designed circuits lead to losses which it is almost impossible to correct operationally, without major redesign of the system.

(e) Poor operations and maintenance - removal of solids build-up in magnetite separators, maintaining the correct level in the separator, worn separator surfaces, leaks in medium lines, blocked or damaged rinse screen surfaces causing the returned medium to be contaminated with fine (and sometimes coarse) coal and refuse material.

The magnetite losses reported in the survey range from 0.75 kilograms per tonne to 3.0 kilograms per tonne, quoted in tonnes of feed to the heavy media section of the plant. It should be noted that many operators quote magnetite consumption based on either a clean coal tonnes or total raw coal tonnes basis. This can sometimes be misleading because the quoted figure can vary considerably due to the influence of yield change and fluctuation in raw coal size analysis. Quoting consumption on the basis of tonnes of feed to the heavy media section (or sections), avoids this problem. An example of this follows:

> Consider a plant operating at 500 tonnes per hour with 25 percent minus 0.6 mm reporting to froth flotation and 75 percent reporting to the heavy media section. The yield of the heavy media section is 80 percent the froth flotation section is 70 percent. If magnetite consumption is 1.5 kilograms per tonne of feed to the heavy media section, then consumption based on raw coal and clean coal are as follows:

Raw Coal: $\frac{1.5 \times 75}{100} =$ 1.125 kilograms per tonne raw coal feed

Total Clean Coal: Consumption for clean coal produced =

$\frac{1.5}{0.8} =$ 1.875 kilograms per tonne clean coal

Overall yield $= (75 \times 0.8) + (25 \times 0.7)$
$= 77.5$ percent

Consumption per tonne total clean coal =

$\frac{1.125}{77.5} \times 100 =$ 1.45 kilograms per tonne

If the percent - 0.6 millimetre changed to 30 percent and the yields of heavy media and froth flotation of clean coal changed to 60 percent and 73 percent respectively. The consumption rates now become:

Raw Coal: $\frac{1.5 \times 0.6}{100}$ = 0.9 kilograms per tonne raw coal feed

Total Clean Coal: Overall yield = $(70 \times 0.73) + (30 \times 0.6)$
= 69.1 percent

Consumption for total clean coal produced =

$\frac{0.9}{69.1} \times 100$ = 1.30 kilograms per tonne clean coal

This assumes a constant consumption rate of 1.5 kilograms per tonne of feed to the heavy media section, which is a reasonable one, because magnetite is lost mainly on clean coal and refuse products. Although it is true that some magnetite losses occur even when the plant is idling, the practice of relating the overall losses to the heavy media feed is more realistic than relating losses to clean coal, which is influenced by yield, or to total raw coal which is influenced by the size analysis.

The consumption of magnetite is also related to the mean grain size of the coal being cleaned in that more magnetite will adhere to fine coal (or refuse) on the drain and rinse screen than to coarse coal.

The amount of medium adhering to the products on a sieve bend plus drain screen (ie. before the rinsing screen) is

$$Q = \frac{950}{da \times \gamma pr} \quad \text{.................... Equation 3.1}$$

where: Q = medium in litres/tonne product
da = average grain size of the product in mm
γpr = average specific gravity of the grain of the product

The Rocky Mountain coals of western Canada are very soft, resulting in a small mean grain size and therefore a higher magnetite consumption than coals found in the other major coalfields of the world. The Dutch State Mines which contributed much to the early development of originally developed magnetite-based, heavy media processes, related adhering magnetite lost to mean size as in equation 3.1 above.

For example, a 10 millimetre by 0.6 millimetre Rocky Mountain coal might have a mean grain size of a 1.8 millimetre while an eastern Canadian coal for the same size fraction might have a mean grain size of 2.7 millimetre.

For the Rocky Mountain coals, the adhering medium at the discharge end of the clean coal drain screen would be:

$$Q = \frac{950}{1.8 \times 1.5} = 352 \text{ litres per tonne product}$$

$$= 0.352 \text{ cubic metre per tonne product}$$

Grams of solid litre of pulp is

$$\frac{P}{P-1} \cdot (d-1) \; . \; 1000 \qquad \text{.................. Equation 3.2}$$

where p = density of magnetite = 4.8

d = density of pulp = 1.5

$$= \frac{4.8}{3.8} \times 0.5 \times 1000$$

$$= 631 \text{ grams per litre}$$

$$\text{weight of magnetite in 352 litres} = \frac{352 \times 631}{1000}$$

$$= 222 \text{ kilograms}$$

which means the magnetite adhering to the coal = 222 kilograms per tonne.

If the rinsing screens are working effectively (ie. sprays and flood boxes are efficient and the screen itself is correctly sized), the rule of thumb is that the adhering magnetite is reduced by a factor of 1000 over the rinsing screen ie. 99.9 percent of the magnetite passed through the rinsing screen so that the adhering magnetite on the clean coal would be 222 grams per tonne = 0.22 kilograms per tonne product.

A generally accepted figure for European, eastern U.S. and South African coals would be 0.15 kilograms per tonne for fine coal (10 millimetre by 0.6 millimetre) and 0.05 kilogram per tonne for coarse coal (+10 millimetre).

The effect of the mean particle size on adhering losses on products on soft coals can clearly be seen, which may partly explain why higher levels of loss were stated by most of the participants in the survey.

The levels recorded in the survey are in the following range:

100 millimetre by 0.6 millimetre feed:	0.7 - 3.0 kilogram per tonne feed to the heavy media circuit(s).

It can be seen that the consumption levels in some Canadian plants are much higher than those suggested for normal practice.

3.3 IMPROVED MEDIUM CIRCULATION AND RECOVERY

3.3.1 Recovery Systems

Canadian coal preparation plants have been designed and built by Canadian, United States, United Kingdom and West German companies. Consequently, these plants and hence, the magnetite circulation and recovery systems contained within them, vary somewhat in design. The original design concepts for media recovery circuits as recommended by the Dutch State Mines (now Stamicarbon) were:

(a) Recovery system employing magnetic separators and magnetite thickening (Figure 3-1).
(b) Recovery system without magnetite thickening (Figure 3-2).
(c) Recovery system with cyclone thickening (Figure 3-3).

More detailed versions of (1) and (b) are shown in Figures 3.4 and 3.5. In these flowsheets, typical recovery circuits for H.M. cyclone and H.M. vessel are given.

In all heavy media plants, the medium adhering to the products is rinsed away with water. The diluted medium thus formed is then directed to the recovery system either by gravity flow or by pumping using heavy duty slurry centrifugal pumps. The feed to the recovery system therefore comprises:

1. The total amount of rinsing water.
2. The adhering medium rinsed from the products.
3. An overflow or bleed, from the heavy media feed.
4. A source of make-up medium to compensate for loss.

The discharge of the recovery system consists of magnetite, normally with a concentration as high as obtainable and non-magnetics tailings in a very dilute slurry, which is bled off as effluent and usually employed for rinsing water as a further precaution against loss.

(a) Recovery System with Magnetite Thicheners

This system can be used for coal cleaning when the feed to the cyclone classifiers of the recovery system contains a magnetite concentration of less than 100 grams per litre, and the density of the underflows of the cyclones is less than 1.3. The diluted medium flows into a pump box and is pumped to cyclone classifiers, the overflow of which reports to a thickener in which the magnetite rapidly settles. The clarified water from the overflow of the thickener is used again in the plant as rinsing water. The underflow of the cyclone reports to the magnetic separator from where the recovered magnetite, having a relative density of over 2.1, reports to the thickener. The overflow of the cyclones, containing finer magnetite particles than the underflow, is mixed with the latter in the thickener to obtain magnetite having the original grain size distribution. The effluent of the magnetic separator is sent to the normal tailings thickener.

(b) Recovery System without Magnetite Thickening

This method of magnetite recovery is applicable where the dilute medium feed to the recovery system contains a concentration of magnetite up to a maximum of 250 grams per litre. The dilute medium reports to magnetic separators where the magnetite is recovered with a relative density of 2.1. The discharge of the magnetic separators containing slurry and a small amount of magnetite is pumped to cyclone classifiers, and the cyclone overflow returns to the rinsing system as clarified water. The cyclone underflow, being the effluent water of the system, reports to a secondary magnetic separator, the width of which is determined by the volume of this underflow.

The slurry discharge from the secondary magnetic separator is removed from the plant. If there is sufficient rinsing water available from other sources, the classifying cyclone step may be eliminated. In this case, the secondary magnetic separator must have the same width as the primary. The effluent water from the secondary magnetic separator can be used as desliming water or be sent directly to the slurry section. The amount of effluent is equal to the amount of fresh water fed to the system.

(c) Recovery System with Cyclone Densifier

When a magnetic separator is fed with a product with a relative density too low to effect the required separation and a thickener cannot be used (cost, space, etc.), the relative density can be raised by using a cyclone densifier as the concentrator. The feed to the cyclone concentrator is the magnetite concentrate from the magnetic separator which must be diluted to about 8 percent by volume before pumping it to the cyclone densifiers. This provides a medium concentration of up to 400 grams per litre.

3.3.2 Magnetic Separators

Stamicarbon (Dutch State Mines) recommends the following operating parameters for magnetic separators:

(a) Concurrent operating drum separators would be selected with permanent ceramic magnets.

(b) The feed concentration to the separator should be a maximum of 250 grams per litre.

(c) The amount of magnetic and non-magnetic solids in the feed should not exceed 16 percent by volume.

(d) The magnets of the separator must be able to give a minimum flux density of 750 Gauss in air at a distance from the drum of 50 millimetres.

(e) The relative density of the recovered magnetite concentrate should be 2.1 if the separator is operating properly.

(f) A separator with an evenly distributed feed will normally not exceed a loss of 0.3 grams per litre.

A schematic diagram of a typical concurrent drum separator is shown in Figure 3-6.

3.3.3 Relative Density Regulation

The control objective of the system is to keep the relative density of the medium constant. In Figure 3-7 the heavy media system is indicated by a rectangle and the flows to and from the medium system causing the relative density to deviate from the required value are indicated by arrows.

The flows into the system are:

- Moisture on the feed
- Magnetite obtained from the recovery system via
  - Magnetic separators;
  - Magnetic thickeners or densifying cyclones;
  - Overdense pump box.

The flow from the system is:

- Medium adhering to the products.

The relative density regulating systems which are employed are:

(a) From mass balance calculations it almost invariably appears that an overflow of medium from the washing system to the recovery system is necessary. This overflow can be taken from:

- The medium in the mixing tank (A)
- Overflow of the washing cyclone (B).

The method using the cyclone overflow is shown in Figure 3-8. This method can be applied when no thickener is used. A signal from the controller is transmitted to a regulatory device which controls the amount of overflowing medium. When the level in the heavy media pump box drops below a certain value, as shown by a level indicator, an amount of make-up magnetite has to be added to the system.

(b) If a thickener or magnetite storage tank is used in the recovery system, the amount of concentrated magnetite going into the system is controlled by a relative density regulating device mounted in the magnetite discharge line from the thickener or storage tank to the heavy media pump box tank. The level in the pump box is controlled by regulating the amount of overflow from the washing system into the recovery system, with medium from the mixing tank. When a higher relative density than desired is being obtained in the washing system (relative density of medium in the pump box), then density control of the system may be achieved by means of regulating a flow of process water into that system. Regulation of medium from the washing system to the recovery system can be achieved by using both the heavy medium overflow and underflow (Figure 3-9).

3.4 CONTROL AND INSTRUMENTATION

Measurement, indication, recording and control in the heavy media plant involves the control of the density, the media, and the level and control of the pump boxes. To obtain an optimum separation in the plant, the density of the medium has to be kept constant within certain limits by automatic means, and to prevent overflow or emptying of the pumps, the levels of liquid in these pump boxes must be controlled.

The density with which the washing media enters the washing vessel is the relative density that requires to be measured. However, the medium also contains raw coal and therefore measurement of the density is not possible at this point. The relative density of the media without coal should therefore be measured at a point in the media stream, prior to the addition of the coal and as far as possible from the point where the last media flow enters the media stream. This will ensure adequate mixing of the various media flows.

In the washing system where product and media are pumped together to the washing cyclone, this point is before the division of the feed launder to the pump box. This point is marked A in Figure 3-10.

In the system where the heavy media cyclone is gravity fed, the recommended points for measurement are shown as A, B or C in Figure 3-11.

For many years, densities were measured by dip tubes recording differential pressure and/or Dp cells. These methods have now been almost totally replaced by nuclear density gauges. Nuclear density gauges actually measure the proportion of solids contained in a slurry, and the signal is then converted to a density reading based on prior calibration to a 'known' standard. If the medium is heavily contaminated with non-magnetics, then a false reading may arise. Some attempts have been made to introduce a magnetic coil type of density gauge into the same line as the nuclear gauge. The magnetic device measures only the proportion of magnetic solids contained in the slurry so that by comparing the two signals obtained it is possible to determine the amount of non-magnetics. These are not often employed in coal preparation at present.

The questionnaire survey indicated that there are two basic types of density control circuits in operation. The most common type takes the dilute medium from the rinsing section of the drain and rinse screens and passes it directly to magnetic separators. The magnetic separator concentrate reports to an overdense tank and the tailings report to dilute medium thickening cyclones. The cyclone overflow is returned to process as rinsing water and the underflow reports to secondary magnetic separators. There are variations in this circuit using a magnetite thickener. The density gauge measuring the correct density relays a signal and overdense magnetite is added on a continuous basis.

Two plants operate with a different density control circuit to the one described above. This employs the principle of keeping the high density medium circulating throughout the circuit which is achieved by sending the magnetic separator concentrate directly to the correct medium pump box as shown in Figure 3-12. This creates a situation where the density of the circulating medium is always tending to rise and a signal is sent from the density gauge to gauge to initiate addition to the circuit. Water is then added automatically to the suction side of the correct medium pump. New medium is only added to 'top-up' the circuit in order to replace losses on products and magnetic separator tailings. A bleed of correct medium is continuously returned to the dilute circuit to ensure that the required amount of medium is always available to the separating unit. This type of control circuit has the advantage of being very responsive to changes in control density, and also less likely to encounter the condition where an operational problem creates a massive depletion of magnetite from the circuit, causing the density to fall to a very low level. Several hours would normally be needed to restore the required operating condition following this type of problem. The circuit as described applied to gravity fed heavy media cyclones as shown in Figure 3-12. For pump fed circuits two correct medium sumps are required, but the control system essentially is the same.

Kilborn believes that the 'rising density' form of control system represents the most effective of the various types currently in use in Canadian plants. The main advantage of this system are:

1. only small quantity of 'top-up' medium is required to provide adjustment in response to demand by the control circuit;
2. fast response is obtainable to corrective signal;
3. rapid indication is received when sudden loss occurs as a result of emergency or leakage;
4. in a multi-stream plant, most streams may be able to continue cleaning despite operating problems encountered in one stream;
5. exact make-up requirements can be measured, enabling media make-up system to be readily automated.

3.5 MAGNETITE PREPARATION

From the questionnaire survey, it can be seen that there is little magnetite preparation of any kind carried out in Canadian plants. One plant does have a magnetite milling circuit, but all the others simply transport the raw magnetite from a stockpile into a mixing box where water is added and the resulting magnetite suspension is transferred to the overdense pump box or to a magnetite thickener.

The questionnaire survey results obtained for eight plants may be summarized as follows:

	No. of Plants
Open Storage	4
Covered Storage	4
Storage in Plant	7
Storage separate from Plant	1
Storage capacity 1,000 Tonnes	0
Storage capacity 1,000 - 5,000 Tonnes	5
Storage capacity 5,000 - 10,000 Tonnes	1
Storage capacity 10,000 Tonnes	2
Milling Circuits	1
No Milling Circuits	7

The results and the associated comments which accompanied them, tend to suggest that covered storage is preferred and a minimum stockpile capacity of 1000 tonnes is necessary to avoid any risk of running short of magnetite. Little interest was expressed in obtaining magnetite milling facilities despite the fact that problems have been encountered with quality control. However, most western Canadian users appear to anticipate a possible need for in-plant milling in the future when current sources of supply are no longer available.

3.6 METHODS OF IMPROVING USAGE AND INPLANT TESTING

Generally, methods of improving usage fall into the following categories:

(a) Design improvements
(b) Operation improvements.

3.6.1 Design Improvements

Redesign of incorrect magnetite circuits and other major design improvements to the original installation have apparently been common occurrences in Canadian plants. Incorrect circuits can arise from design faults of the original circuit or as a result of modifications that have been incorrectly made to circuits. This latter occurrence is a common one, usually arising as a result of achieving 'local' improvements which cause an overall detrimental effect to the total recovery system. A good example of this is the replacement of shower boxes by high pressure sprays on the drain and rinse screens for rinsing off adhering medium. This can more than double the amount of water passing into the dilute system, thereby risking serious overloading of magnetic separators in terms of flowrate.

Examples of fairly common general improvements which may be made to the initial design include the following:

1. Introduction of more accurate density gauges or repositioning of existing ones to improve accuracy and response to change in operating density.

2. Changing recovery system flowsheet to a more efficient one, eg. replacing magnetite thickener by thickening cyclones.

3. Providing more primary magnetic separator capacity.

4. Alternation of media make-up or distribution circuits other than normal fine tuning.

5. Introducing a scavenging circuit, eg. installing a Magnadisc separator.

6. Installation of de-magnetization coils to improve media stability.

Any of the above changes would only be carried out following careful re-examination of the original design and the design criteria used. The ramifications of any proposed design change must be fully examined to avoid any risk of causing detrimental effects elsewhere in the plant. Other forms of improvement may include replacement of certain types of equipment with other more effective types. In this regard, design improvements may be made to the magnetic separators.

Examples of design improvements of magnetic separators are:

1. Replacement of carbon steel in magnetic separators with stainless steel to combat corrosion caused by the low pH of slurries.

2. Improved feed manifolds or introduction of a feed box to improve the feed distribution to the surface of the drum.

3. Improved tailings control, overflow and concentrate removal systems by changing orifice plate or spigot sizes.

4. Matching magnetic field strength and gradient to suit correct application. Primary drum separators usually have to handle high feed rates and secondary separators attempt to recover all the magnetics from a feed with a low magnetic concentration.

5. Inclusion of strainer screens in the feed system to prevent oversize material from reporting to the magnetic separators and damaging the surface of the drum or blocking discharge spigots.

6. Limitation of feed volume to separators (if possible) to practical targets for the specific size of machine employed, ie. avoid overloading. Guidance may be obtained from most of the major separator manufacturers.

7. Improved design of drums for better maintenance. Replacement of drums should be easier and access to tailings discharge (for control purposes) should be improved.

3.5.2 Operational Improvement

The implementation of improved operating and maintenance procedures normally represents the most effective means of obtaining an efficient system. In this regard it is most important to adopt a systematic approach to making the necessary improvements. This should avoid the risk of carrying out changes which create improvements that are subsequently negated by further changes to the system. Although this is not always totally avoidable, an overall net improvement should be possible as monitored by regular checking by operating personnel. Examples of improved operating procedures are:

1. Keeping drum faces of magnetic separators in good condition and replacing drums when worn.

2. Maintaining a good distribution of feed to the magnetic separators. Periodically cleaning launders and unblocking distributors and manifolds.

3. Maintaining the correct level in the magnetic separator by using correct orifices or spigot openings in the tailings discharge launder. Periodic checks should be made for blockages and for cleanliness.

4. Regularly cleaning out shower boxes on the drain and rinse screens and all head boxes or distribution boxes within the media distribution system.

5. Regularly sampling circulating medium to check for build-up of non-magnetics content.

6. Sampling and testing all new deliveries of magnetite and periodically testing samples of circulating medium to ensure that the size distribution is acceptable.

7. Periodically checking density gauges, demagnetization coils and other measuring equipment to ensure proper function.

8. Checking media distribution system for leaks, wear or damage and arranging for rapid renovation.

In terms of in-plant testing, the questionnaire survey indicates that the majority of the plants do little testing of magnetite, other than sizing at 325 mesh and the determination of magnetics content. Some plants do no testing of magnetite. The survey results are summarized as follows:

	No. of Plants
Sizing	
No testing	3
Wet Screening (325 Mesh Only)	4
Wet Screening (Below 325 Mesh)	2
Other Sizing Methods (Air Elutriation)	1
Magnetics Content	
No Testing	2
Davis Tube	5
MagnaChute	1
Moisture Content	
No Testing	3
ASTM Air-drying Method	5
Density	
No Testing	6
ASTM Pycnometer Method	2
Demagnetization Properties	
No Testing	8
Settling Tests	
No Testing	7
F5 Method	1

The numbers of tests carried out per year varies from 35 to 2. Two plants tested each rail car (30-35 per year). Two plants did no testing at all.

Testing by the supplier was found to vary with supplier. Supplier testing is summarized as follows:

Supplier A

Sizing: - Reported by some plants that supplier tests from 100 Mesh through to 7 Microns
- Reported by some plants that supplier tests at 325 Mesh only.
Magnetics: - Reports Magnetics by Davis Tube Method
% Fe: - Supplier Tests - No Details
% Moisture: - Supplier Tests (ASTM)
Density: - No Testing
Settling Rate: - No Testing
Demagnetization: - No Testing

Supplier B

Sizing: - Reported by some plants that supplier does not test
- Reported by some plants that supplier tests at 150,200 and 325 Mesh
Magnetics: - Supplier Tests (Method not reported)
% Fe: - No Testing
% Moisture: - No Testing
Density: - Supplier Tests (ASTM)
Settling Rate: - No Testing
Demagnetization: - No Testing

It would therefore appear from the questionnaire survey that each of the conditions of the sale of magnetite, in particular the form of the specification of the product, appears to be very arbitrary between each purchaser and both of the two suppliers mentioned in the survey,

3.5.3 Scavenging

If existing magnetite recovery circuits have been "fine-tuned" to the point where no further gains in magnetite recovery can be made with the existing circuit, a scavenger circuit may be considered for treating the magnetic separator tailings. One example, which is now fairly common in Canadian plants, is to use a magnetic disc separator of the Magnadisc type.

Drum separators are normally fed 10-15 percent total solids by weight, which consists of about 30 percent magnetite. The Magnadisc is not effective for streams with high magnetite concentration. It works better on flows with solids between 5-40 percent and low magnetite concentrations (less than 1 percent total solids). These are representative figures for thickener underflow and drum separator tailings. Discs set 20 millimetres apart subdivide the feed to the unit. These discs are 3 millimetres in diameter and 10 millimetres thick, and each disc contains about 5,000 permanent magnets covered on each side by a 0.5 millimetre thick stainless steel plate. The large contact area provided by the plates combined with the short distance between the magnets and the slurry permits efficient recovery. Each disc is designed to recover 27 kilograms of magnetite per hour from a feed rate of 15 cubic metres per hour. Increasing disc speed will raise this capacity but at the expense of recovery efficiency.

An example of a typical Canadian installation is given in the flowsheet shown earlier in Figure 3-12.

3.7 PROPOSED RESEARCH AND DEVELOPMENT WORK

In terms of plant procedures, research and development could be beneficial in the following areas:

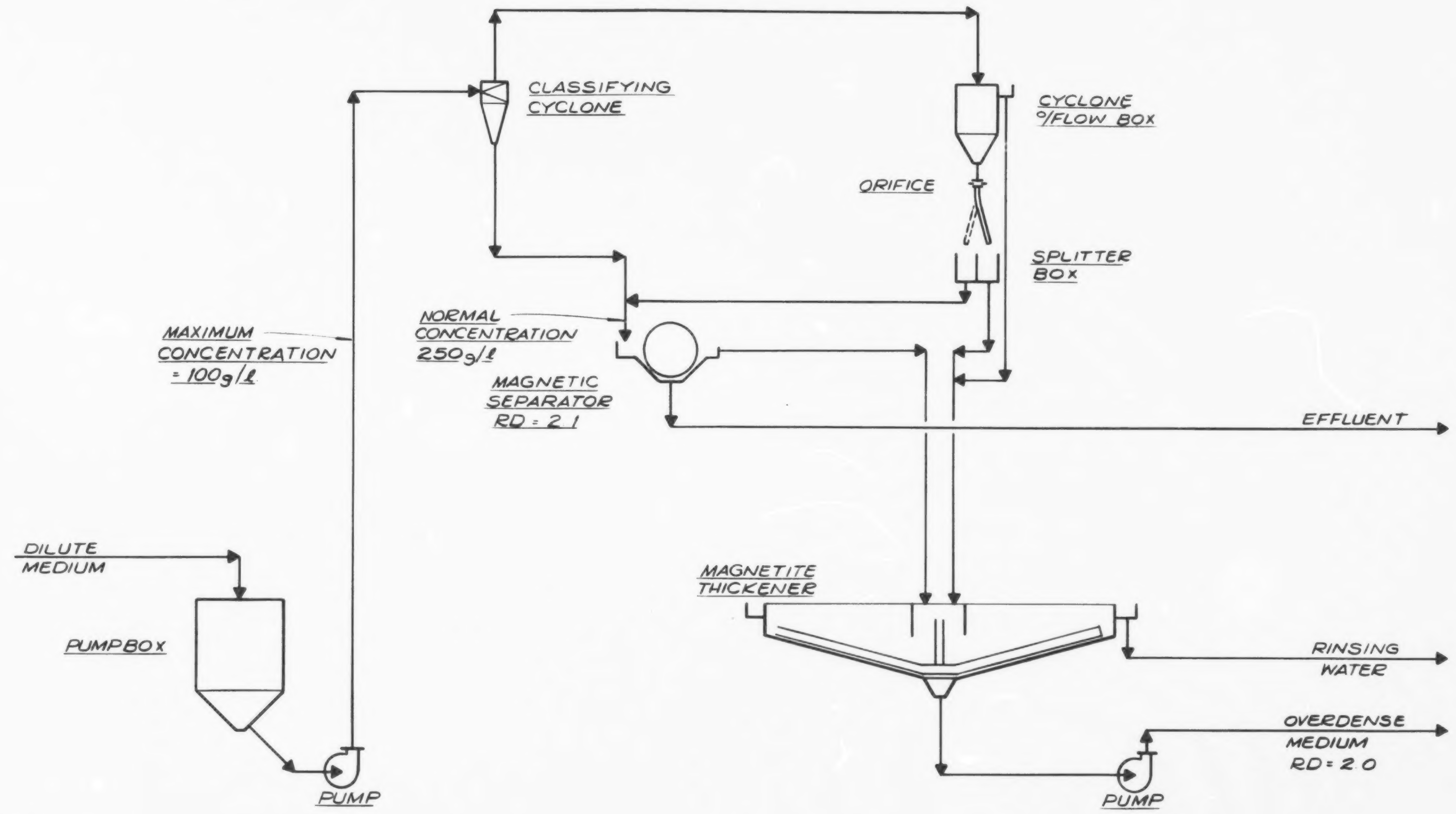
1. Preparation of standards for in-plant testing of magnetite quality including procedures on:
   - Size analysis
   - Percent Magnetics/Non-magnetics
   - Stability
   - Density
   - Moisture
   - Total Iron
   - Ease of Demagnetization

   As well as detailing procedures, acceptable levels should be established and an indication of problems which might arise if these standards are not met.

2. A research program on the practical effects of demagnetization of medium in the plant.

3. Assessment of the effectiveness of scavenger circuits and under what circumstances they may be economically effective.

4. Preparation of guidelines on magnetic separator operations including key operational items such as flow rates, densities, percent magnetics, percent solids and anticipated quality parameters for concentrate and tailings for both primary and secondary separators.


CLASSIFYING CYCLONE
CYCLONE O/FLOW BOX
ORIFICE
SPLITTER BOX
MAXIMUM CONCENTRATION = 100g/l
NORMAL CONCENTRATION 250g/l
MAGNETIC SEPARATOR RD = 2.1
EFFLUENT
DILUTE MEDIUM
PUMPBOX
PUMP
MAGNETITE THICKENER
RINSING WATER
OVERDENSE MEDIUM RD = 2.0
PUMP

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

KILBORN ENGINEERING (B.C.) LTD.

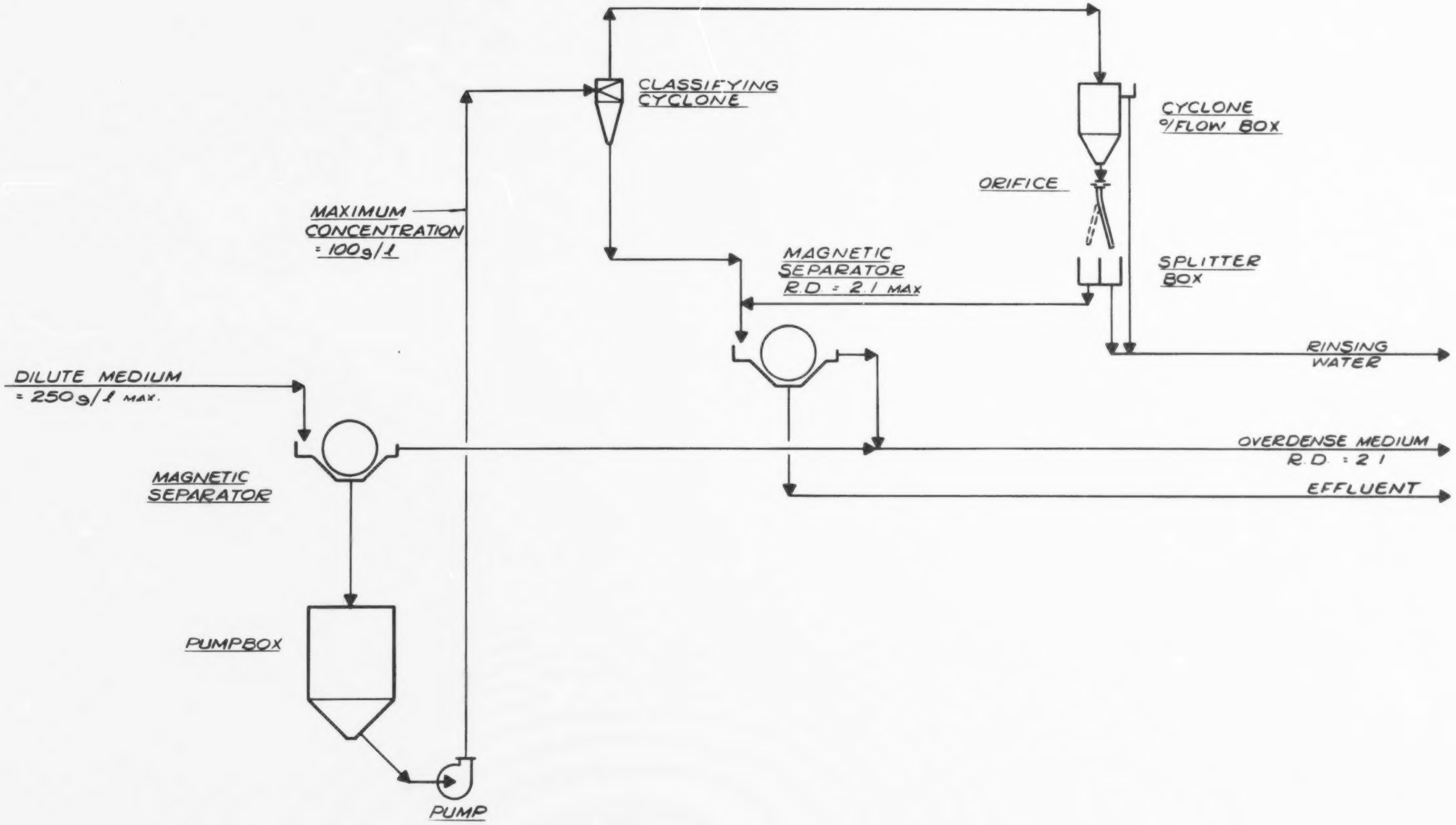
SECTION GENERAL
PROJECT No. 7814 15
AREA No.
DRAWN B. ROSS
CHECKED
EQMT. No.
DATE 86·3·26
APPROVED
PROJ. APPR.

TITLE

HEAVY MEDIA RECOVERY SYSTEM
EMPLOYING MAGNETITE THICKENER
(EMPLOYED IN CANADA)

SHEET No.
CONT. ON
DWG. No. FIGURE 3.1
REV. No.

BCIL 68878-K.E.


CLASSIFYING CYCLONE
CYCLONE O/FLOW BOX
ORIFICE
MAXIMUM CONCENTRATION = 100g/l
MAGNETIC SEPARATOR R.D. = 2.1 MAX
SPLITTER BOX
RINSING WATER
DILUTE MEDIUM = 250g/l MAX.
OVERDENSE MEDIUM R.D. = 2.1
MAGNETIC SEPARATOR
EFFLUENT
PUMPBOX
PUMP

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

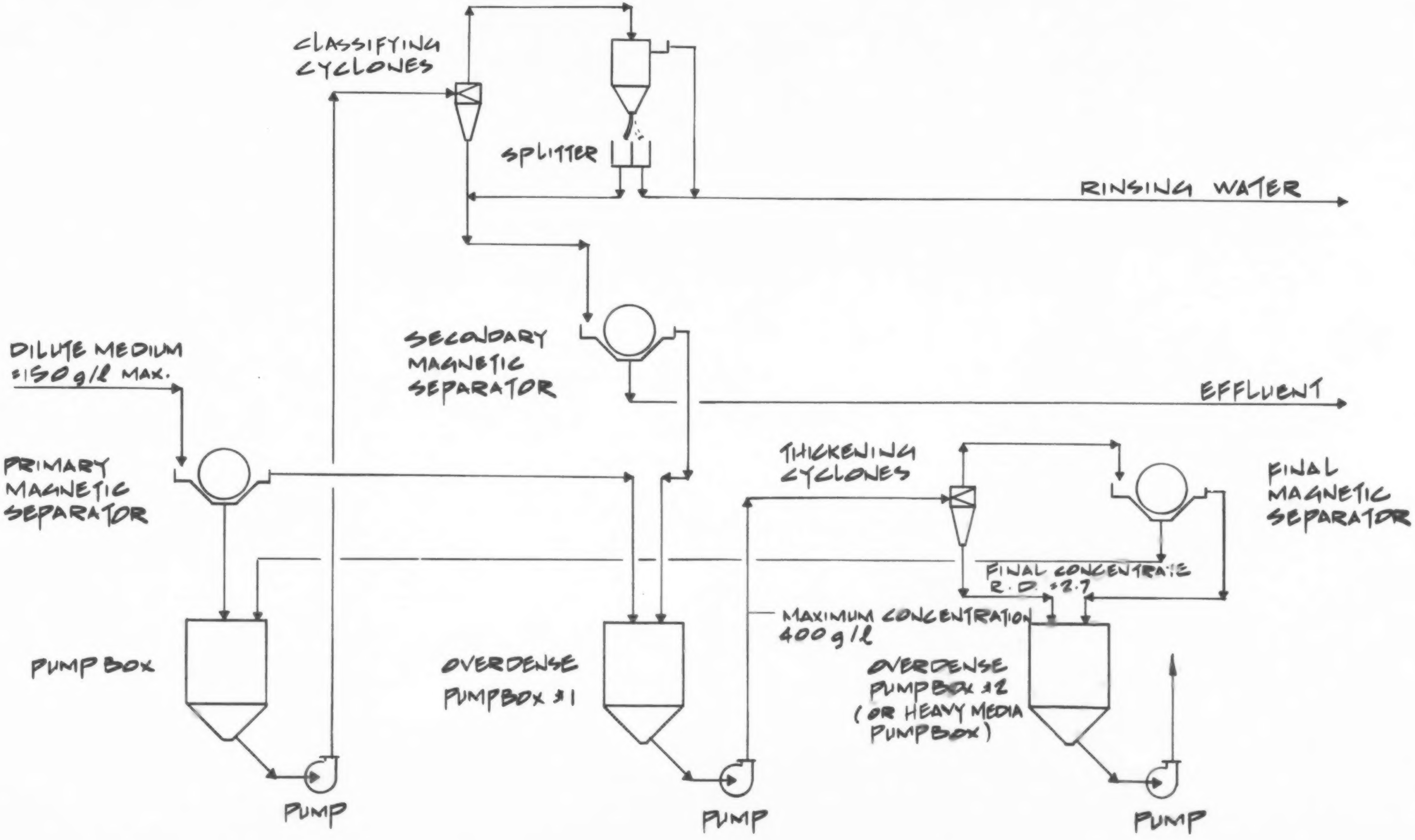
KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL	PROJECT No. 7814 · 15	AREA No.
DRAWN B. ROSS	CHECKED	EQMT. No.
DATE 86 3 26	APPROVED	PROJ. APPR.

TITLE
HEAVY MEDIA RECOVERY SYSTEM
EMPLOYING MAGNETIC SEPARATORS
(EMPLOYED IN CANADA)

SHEET No.	CONT. ON	DWG. No.	REV. No.
		FIGURE 3.2	

BCIL 8897B-K.E.


CLASSIFYING CYCLONES
SPLITTER
RINSING WATER
SECONDARY MAGNETIC SEPARATOR
DILUTE MEDIUM ±150 g/l MAX.
EFFLUENT
PRIMARY MAGNETIC SEPARATOR
THICKENING CYCLONES
FINAL MAGNETIC SEPARATOR
FINAL CONCENTRATE R.D. ±2.7
MAXIMUM CONCENTRATION 400 g/l
PUMP BOX
OVERDENSE PUMPBOX #1
OVERDENSE PUMPBOX #2 (OR HEAVY MEDIA PUMPBOX)
PUMP
PUMP
PUMP

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL
PROJECT No. 7816-15
AREA No.
DRAWN PL
CHECKED
EQMT. No.
DATE 86·3·26
APPROVED
PROJ. APPR.

TITLE
HEAVY MEDIA RECOVERY SYSTEM FOR VERY LOW FEED CONCENTRATION (CURRENTLY NOT USED IN CANADA

SHEET No.
CONT. ON
DWG. No. FIGURE 3.3
REV. No.

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

BCIL 8697B-K.S.

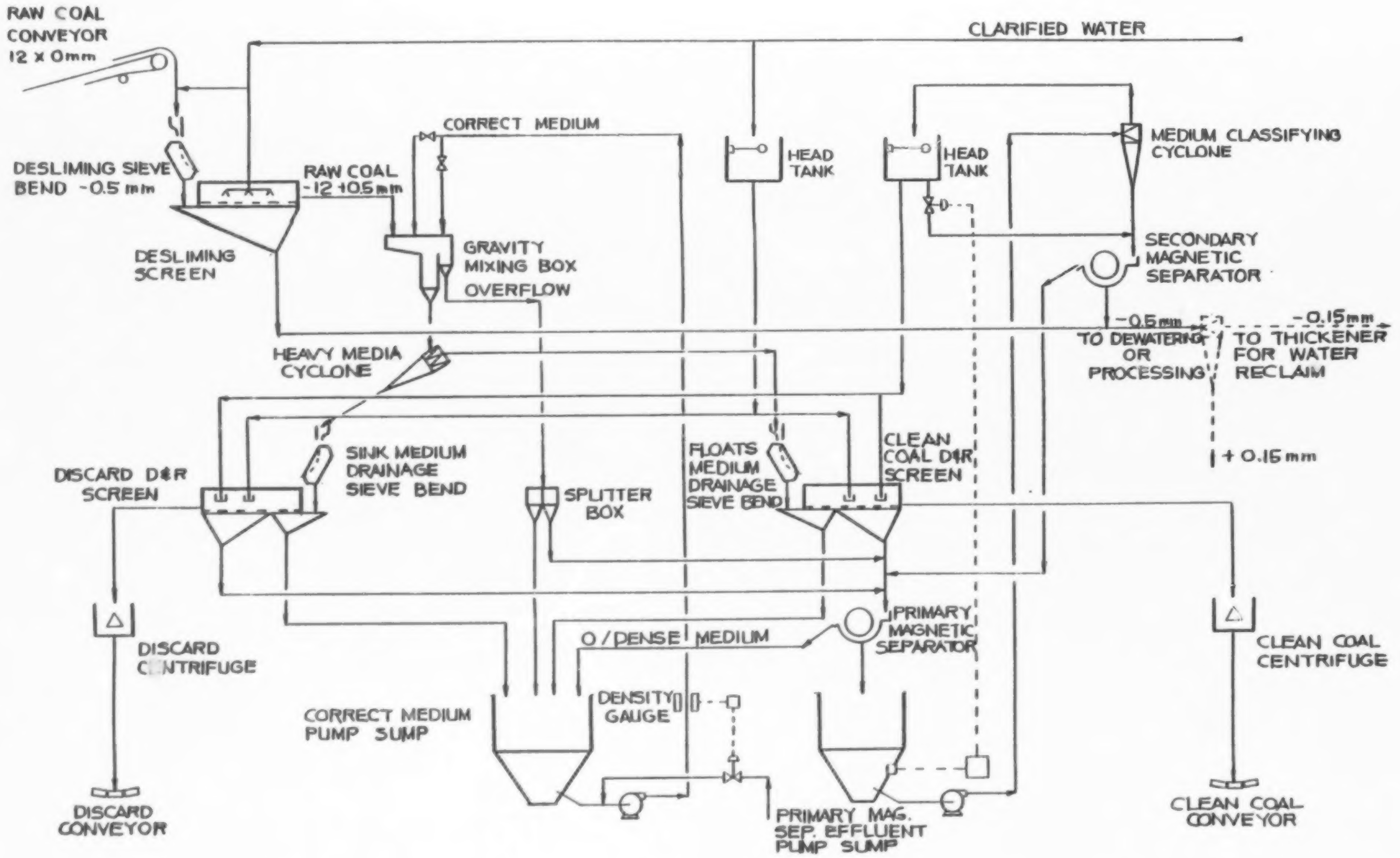

RAW COAL
CONVEYOR
12 x 0mm
CLARIFIED WATER
CORRECT MEDIUM
DESLIMING SIEVE
BEND -0.5 mm
RAW COAL
-12 +0.5 mm
HEAD
TANK
HEAD
TANK
MEDIUM CLASSIFYING
CYCLONE
DESLIMING
SCREEN
GRAVITY
MIXING BOX
OVERFLOW
SECONDARY
MAGNETIC
SEPARATOR
-0.5 mm
-0.15 mm
TO DEWATERING
OR
PROCESSING
TO THICKENER
FOR WATER
RECLAIM
HEAVY MEDIA
CYCLONE
+0.15 mm
DISCARD D&R
SCREEN
SINK MEDIUM
DRAINAGE
SIEVE BEND
SPLITTER
BOX
FLOATS
MEDIUM
DRAINAGE
SIEVE BEND
CLEAN
COAL D&R
SCREEN
DISCARD
CENTRIFUGE
O/DENSE MEDIUM
PRIMARY
MAGNETIC
SEPARATOR
CLEAN COAL
CENTRIFUGE
CORRECT MEDIUM
PUMP SUMP
DENSITY
GAUGE
DISCARD
CONVEYOR
PRIMARY MAG.
SEP. EFFLUENT
PUMP SUMP
CLEAN COAL
CONVEYOR

FIGURE 3-4 TYPICAL FLOWSHEET OF HEAVY MEDIA CYCLONE CIRCUIT

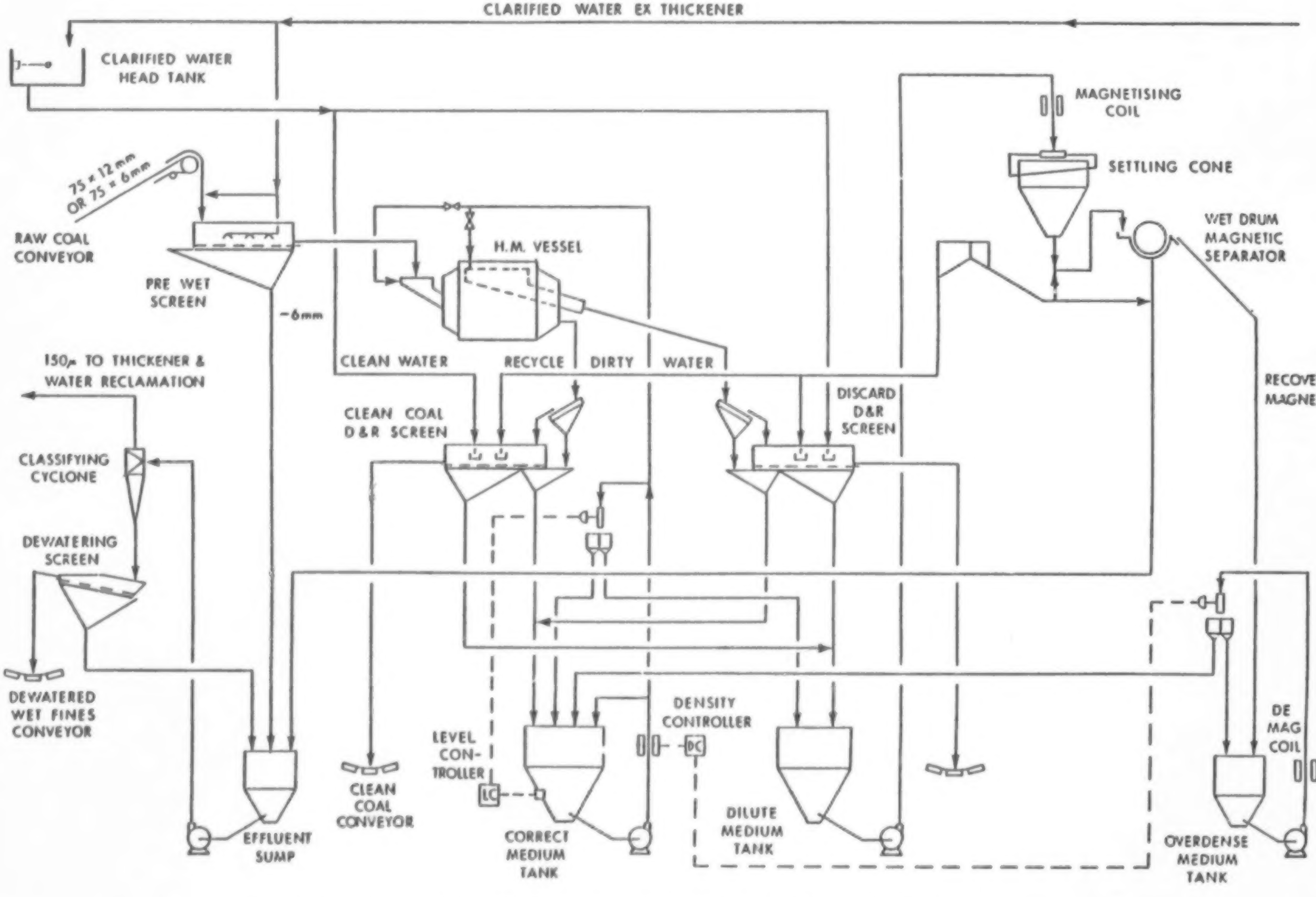
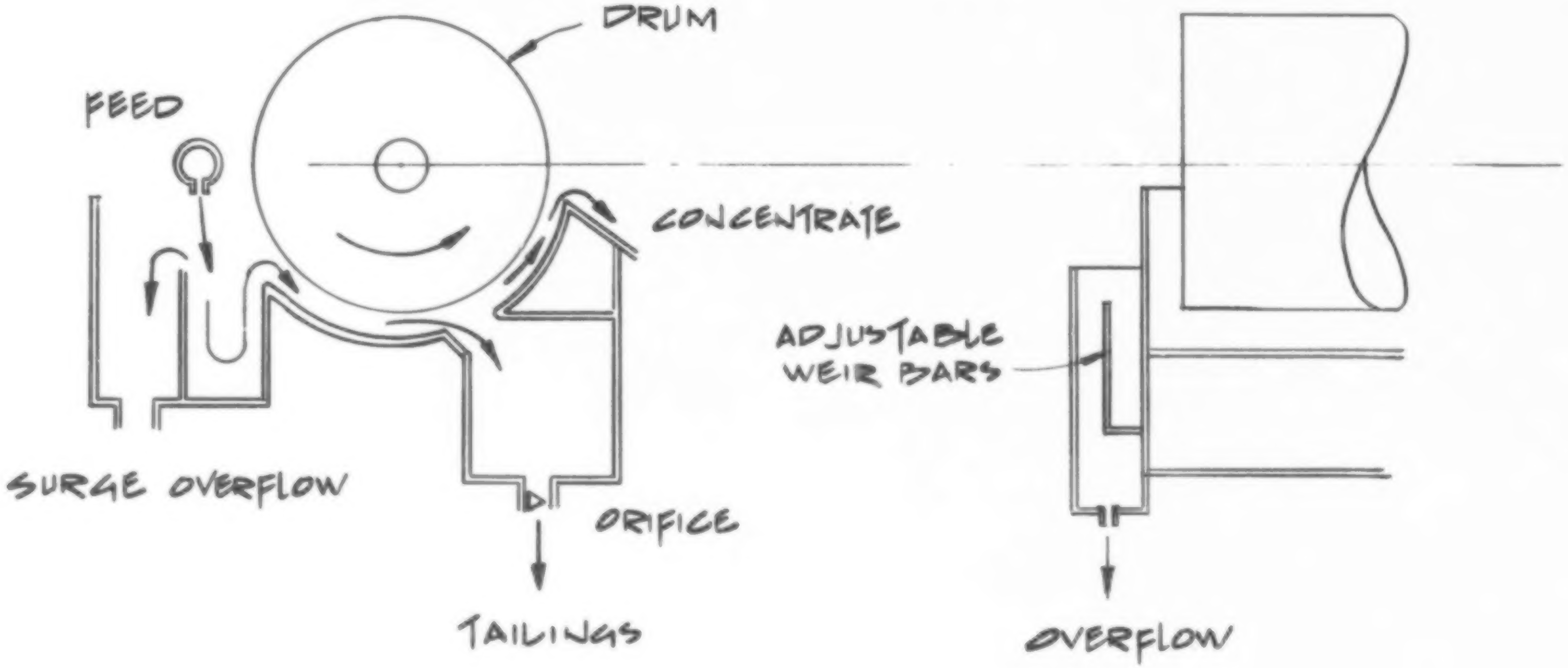

CLARIFIED WATER EX THICKENER
CLARIFIED WATER HEAD TANK
75 x 12 mm OR 75 x 6 mm
RAW COAL CONVEYOR
PRE WET SCREEN
-6mm
H.M. VESSEL
CLEAN WATER
RECYCLE
DIRTY
WATER
MAGNETISING COIL
SETTLING CONE
WET DRUM MAGNETIC SEPARATOR
RECOVERED MAGNETITE
150µ TO THICKENER & WATER RECLAMATION
CLASSIFYING CYCLONE
DEWATERING SCREEN
DEWATERED WET FINES CONVEYOR
CLEAN COAL D&R SCREEN
DISCARD D&R SCREEN
DENSITY CONTROLLER
DC
LEVEL CON-TROLLER
LC
EFFLUENT SUMP
CLEAN COAL CONVEYOR
CORRECT MEDIUM TANK
DILUTE MEDIUM TANK
DE MAG COIL
OVERDENSE MEDIUM TANK

FIGURE 3-5 TYPICAL FLOWSHEET OF HEAVY MEDIA VESSEL CIRCUIT


DRUM
FEED
CONCENTRATE
SURGE OVERFLOW
ORIFICE
TAILINGS
ADJUSTABLE
WEIR BARS
OVERFLOW

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL	PROJECT No. 7814-15	AREA No.
DRAWN PL	CHECKED	EQMT. No.
DATE 86-3-26	APPROVED	PROJ. APPR.

TITLE
HEAVY MEDIA RECOVERY SYSTEM
WET DRUM SEPARATOR WITH
CONCURRENT OPERATION

SHEET No.	CONT. ON	DWG. No.	REV. No.
		FIGURE 3.6	

SCIL 58878-K.E.

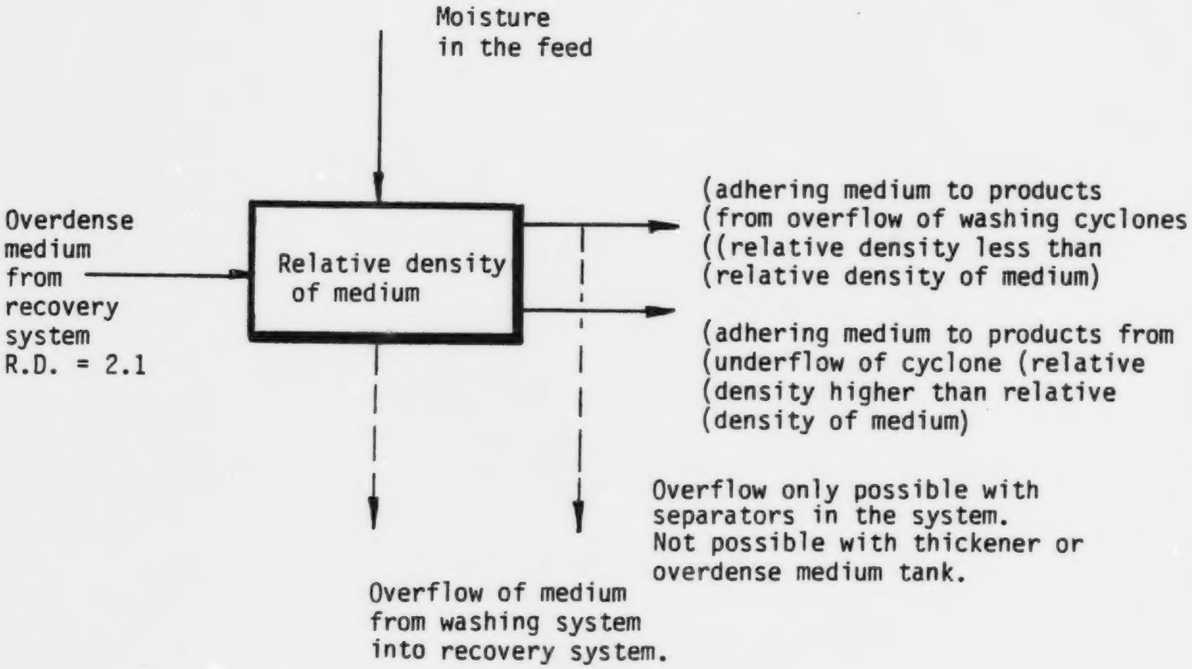
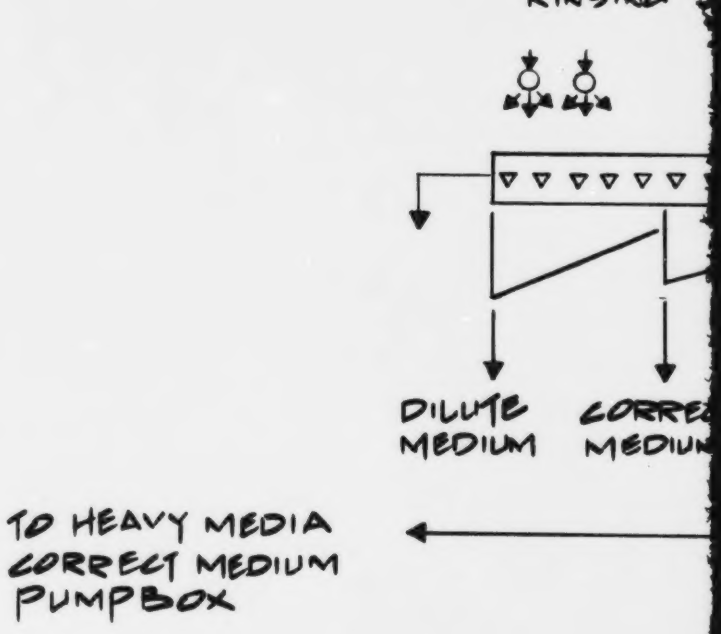
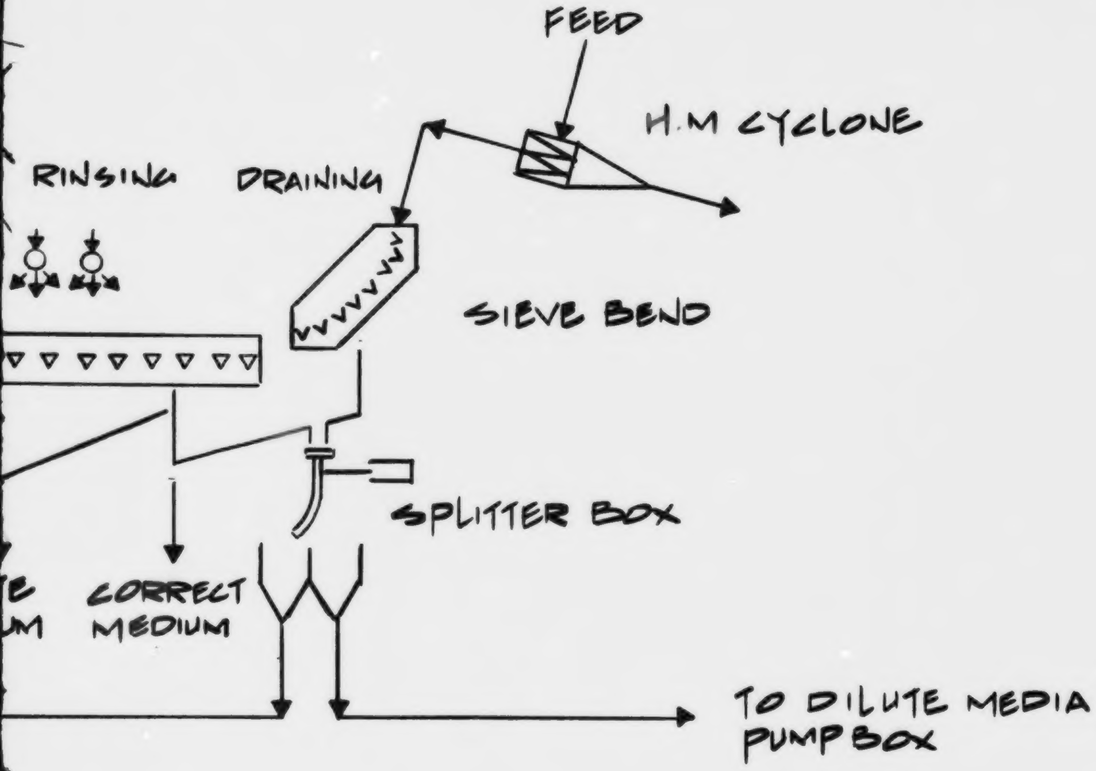

Moisture
in the feed
Overdense
medium
from
recovery
system
R.D. = 2.1
Relative density
of medium
(adhering medium to products
(from overflow of washing cyclones
((relative density less than
(relative density of medium)
(adhering medium to products from
(underflow of cyclone (relative
(density higher than relative
(density of medium)
Overflow only possible with
separators in the system.
Not possible with thickener or
overdense medium tank.
Overflow of medium
from washing system
into recovery system.

FIGURE 3-7 FLOWS IN AND OUT OF A HEAVY MEDIA SYSTEM


RINSING
DILUTE MEDIUM
CORRE
MEDIU
TO HEAVY MEDIA CORRECT MEDIUM PUMPBOX

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION


FEED
H.M CYCLONE
RINSING
DRAINING
SIEVE BEND
SPLITTER BOX
E
UM
CORRECT
MEDIUM
TO DILUTE MEDIA
PUMP BOX

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

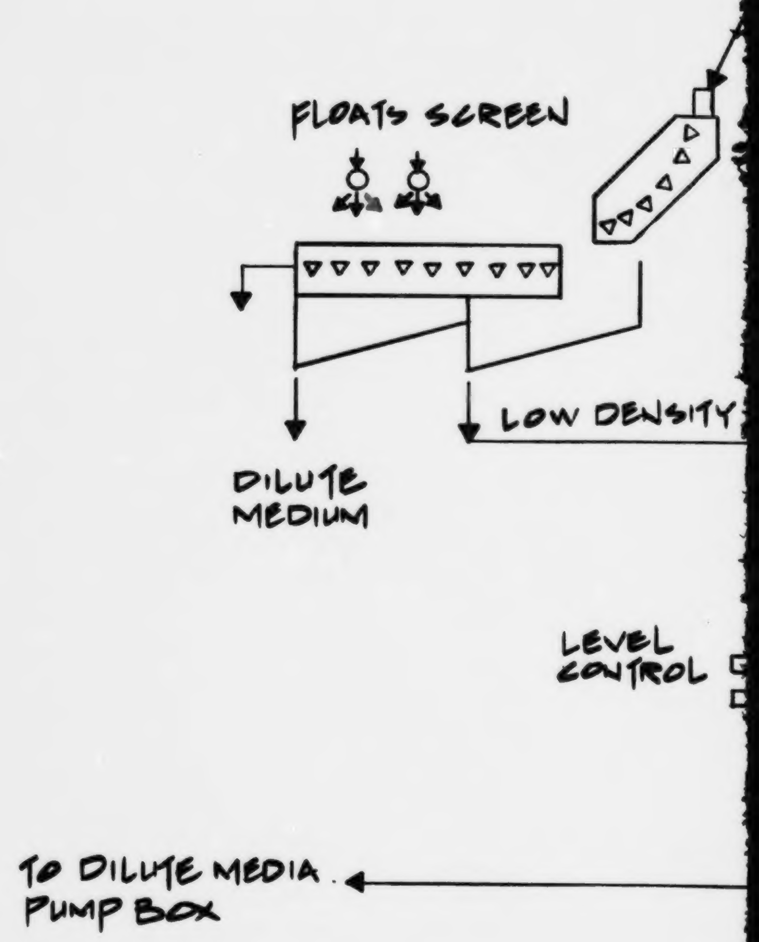
KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL	PROJECT No. 7814-15	AREA No.
DRAWN PL	CHECKED	EQMT. No.
DATE 86-3-26	APPROVED	PROJ. APPR.

TITLE

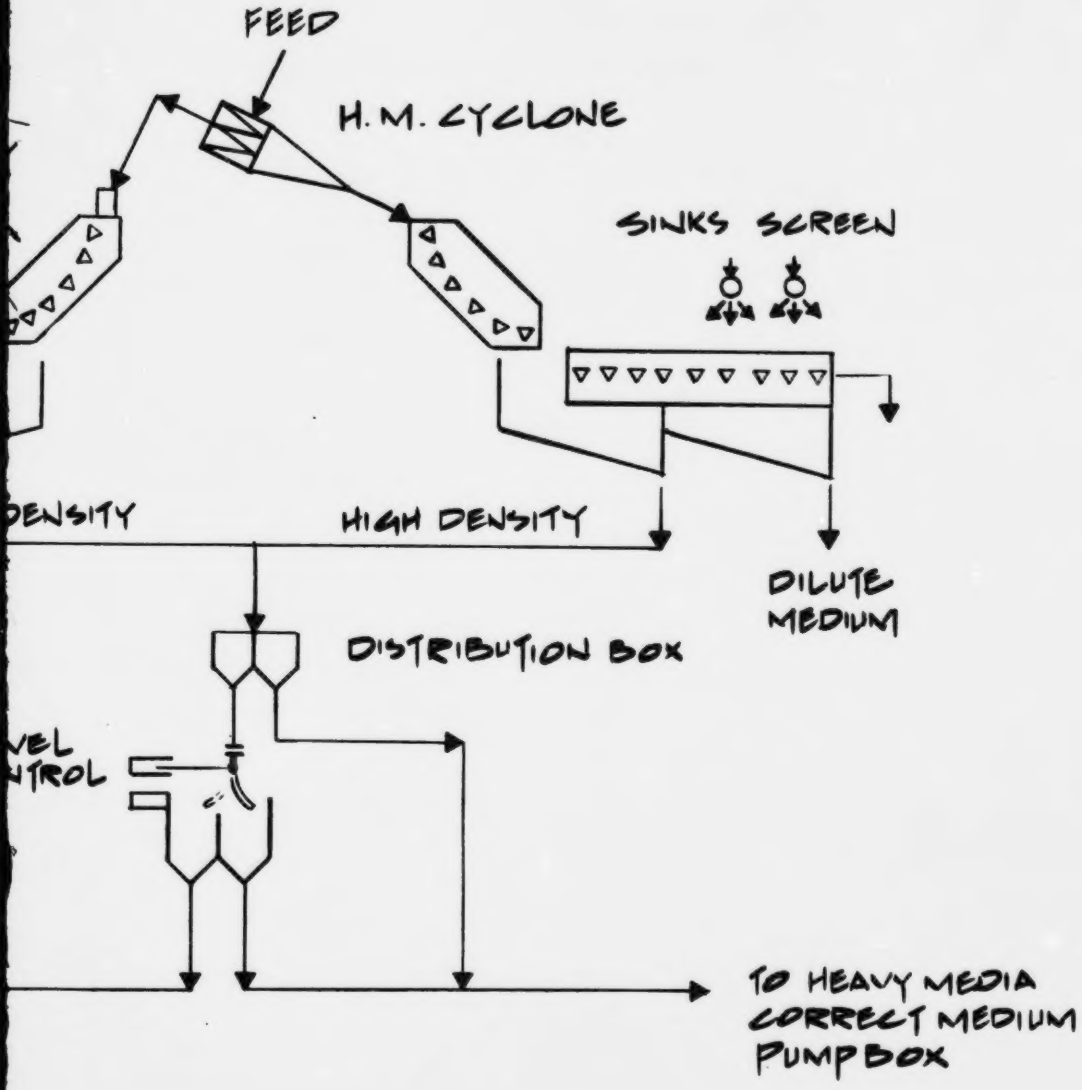
HEAVY MEDIA RECOVERY SYSTEM
WITHOUT THICKENER

SHEET No.	CONT. ON	DWG. No. FIGURE 3.8	REV. No.


FLOATS SCREEN
LOW DENSITY
DILUTE MEDIUM
LEVEL CONTROL
TO DILUTE MEDIA PUMP BOX

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

BCIL 5857B-K.E.


FEED
H.M. CYCLONE
SINKS SCREEN
DENSITY
HIGH DENSITY
DILUTE MEDIUM
DISTRIBUTION BOX
VEL
NTROL
TO HEAVY MEDIA CORRECT MEDIUM PUMPBOX

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

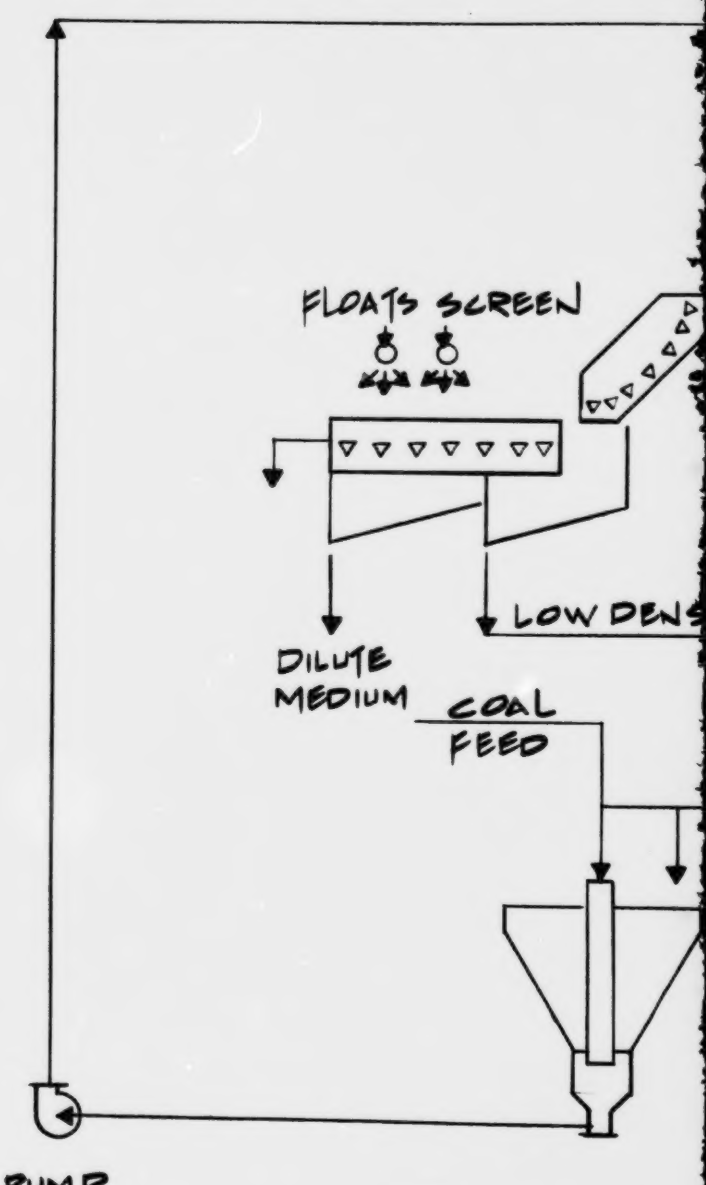
KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL	PROJECT No. 7814-15	AREA No.
DRAWN PL	CHECKED	EQMT. No.
DATE 86-3-26	APPROVED	PROJ. APPR.

TITLE

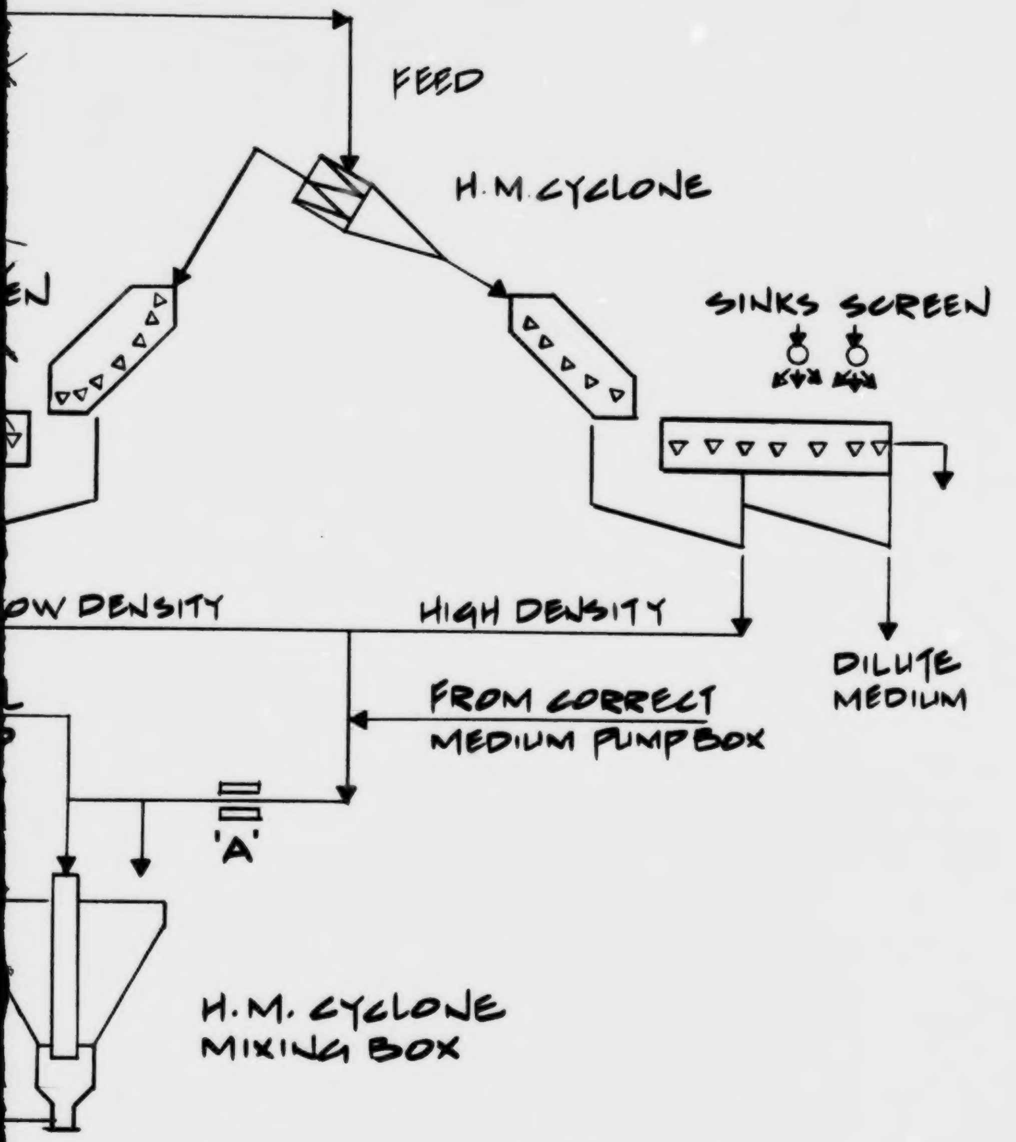
HEAVY MEDIA RECOVERY SYSTEM USING HIGH AND LOW DENSITY BLEED

SHEET No.	CONT. ON	DWG. No.	REV. No.
		FIGURE 3.9	


FLOATS SCREEN
LOW DENS
DILUTE MEDIUM
COAL FEED
PUMP

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

BCIL 99978-K.E.



FEED
H.M. CYCLONE
EN
SINKS SCREEN
OW DENSITY
HIGH DENSITY
DILUTE MEDIUM
FROM CORRECT MEDIUM PUMPBOX
'A'
H.M. CYCLONE MIXING BOX

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

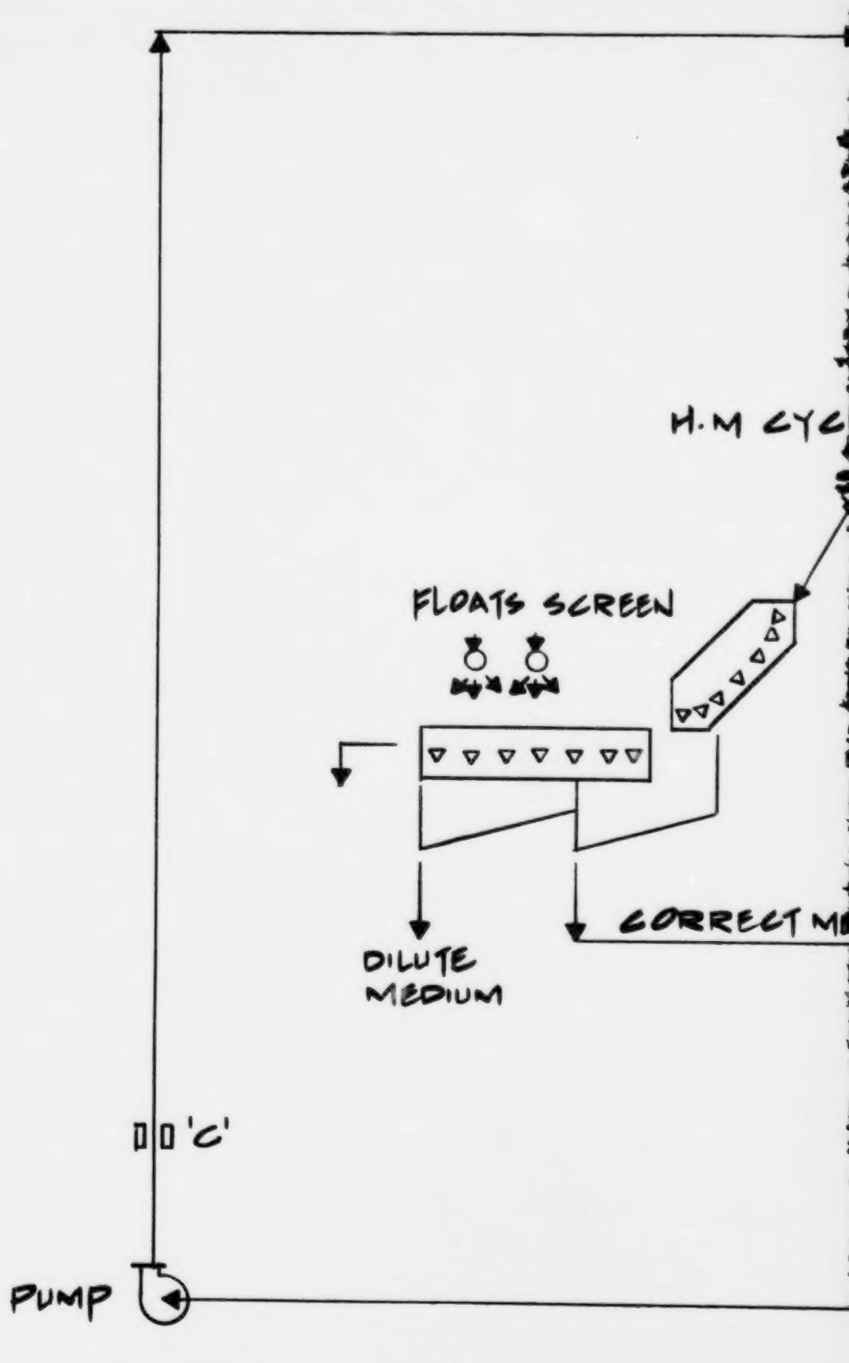
KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL	PROJECT No. 7814-15	AREA No.
DRAWN PL	CHECKED	EQMT. No.
DATE '86-3-26	APPROVED	PROJ. APPR.

TITLE

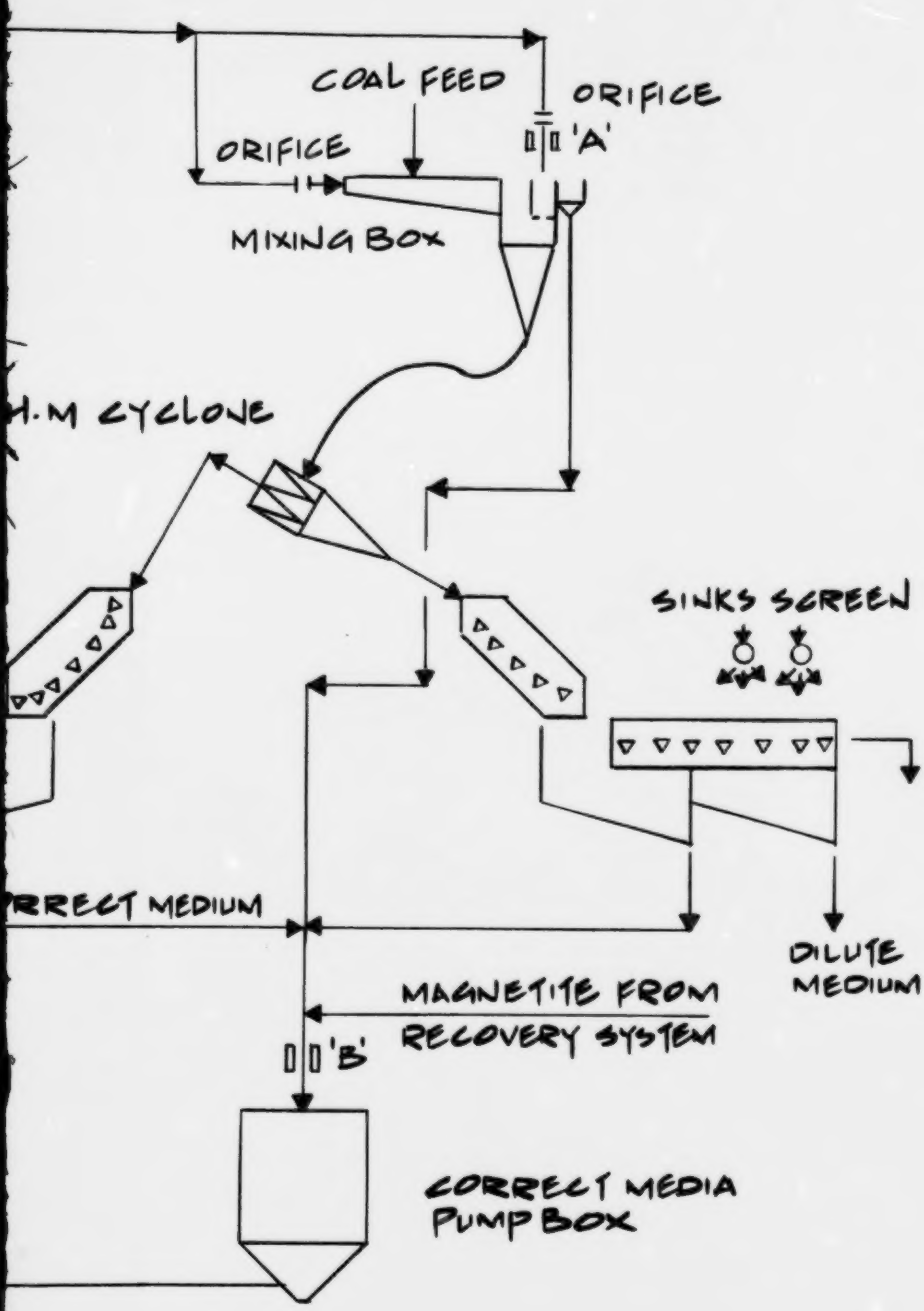
PUMP-FED HEAVY MEDIA CYCLONE SYSTEM SHOWING LOCATION OF DENSITY GAUGE

SHEET No.	CONT. ON	DWG. No.	REV. No.
		FIGURE 3.10	


H.M CYC
FLOATS SCREEN
CORRECT M
DILUTE MEDIUM
'C'
PUMP

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

SCIL 58878-K.E.


COAL FEED
ORIFICE
ORIFICE
'A'
MIXING BOX
H.M CYCLONE
SINKS SCREEN
RRECT MEDIUM
DILUTE MEDIUM
MAGNETITE FROM RECOVERY SYSTEM
'B'
CORRECT MEDIA PUMP BOX

CLIENT: SUPPLY & SERVICES CANADA

LOCATION: DEVON COAL RESEARCH CENTRE

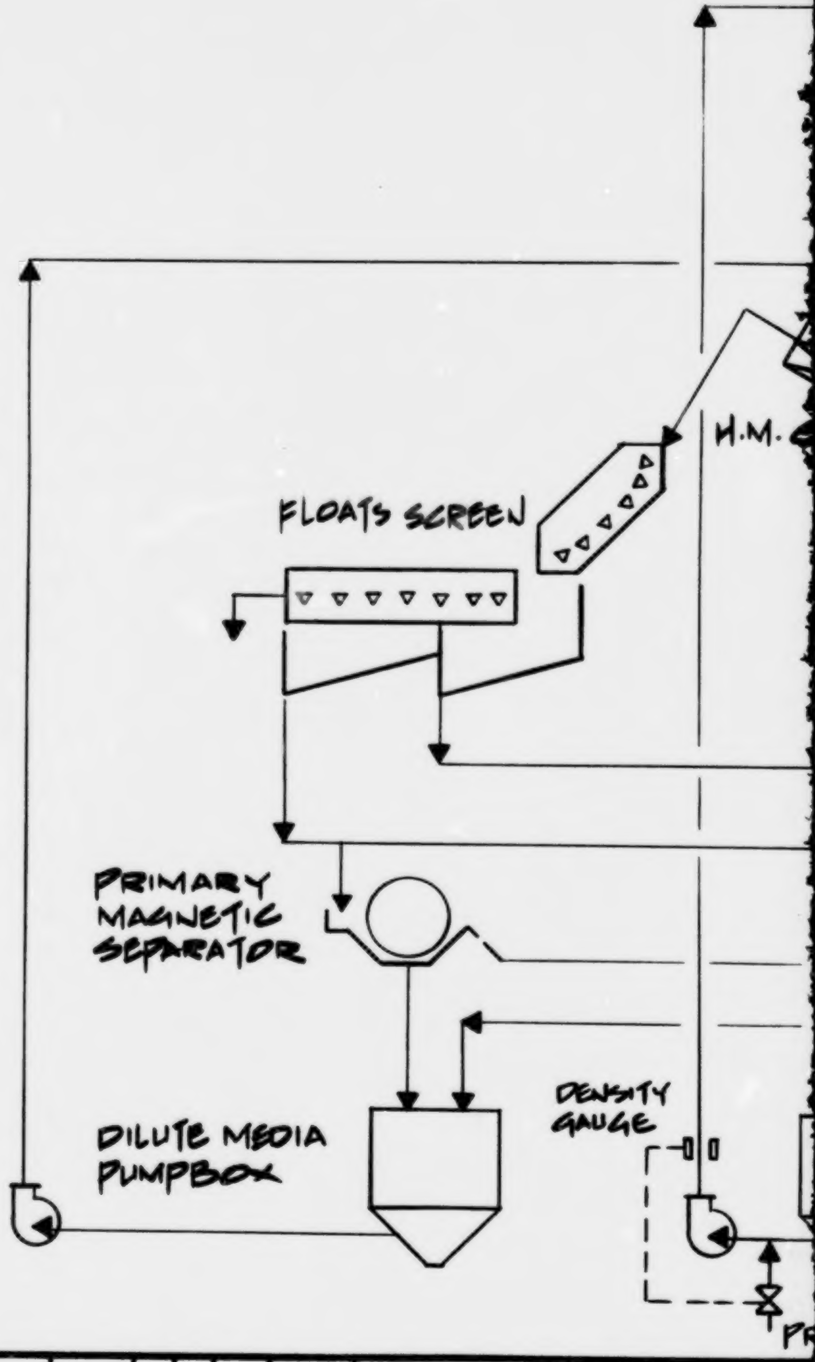
KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL	PROJECT No. 7814-15	AREA No.
DRAWN PL	CHECKED	EQMT. No.
DATE '86-3-26	APPROVED	PROJ. APPR.

TITLE

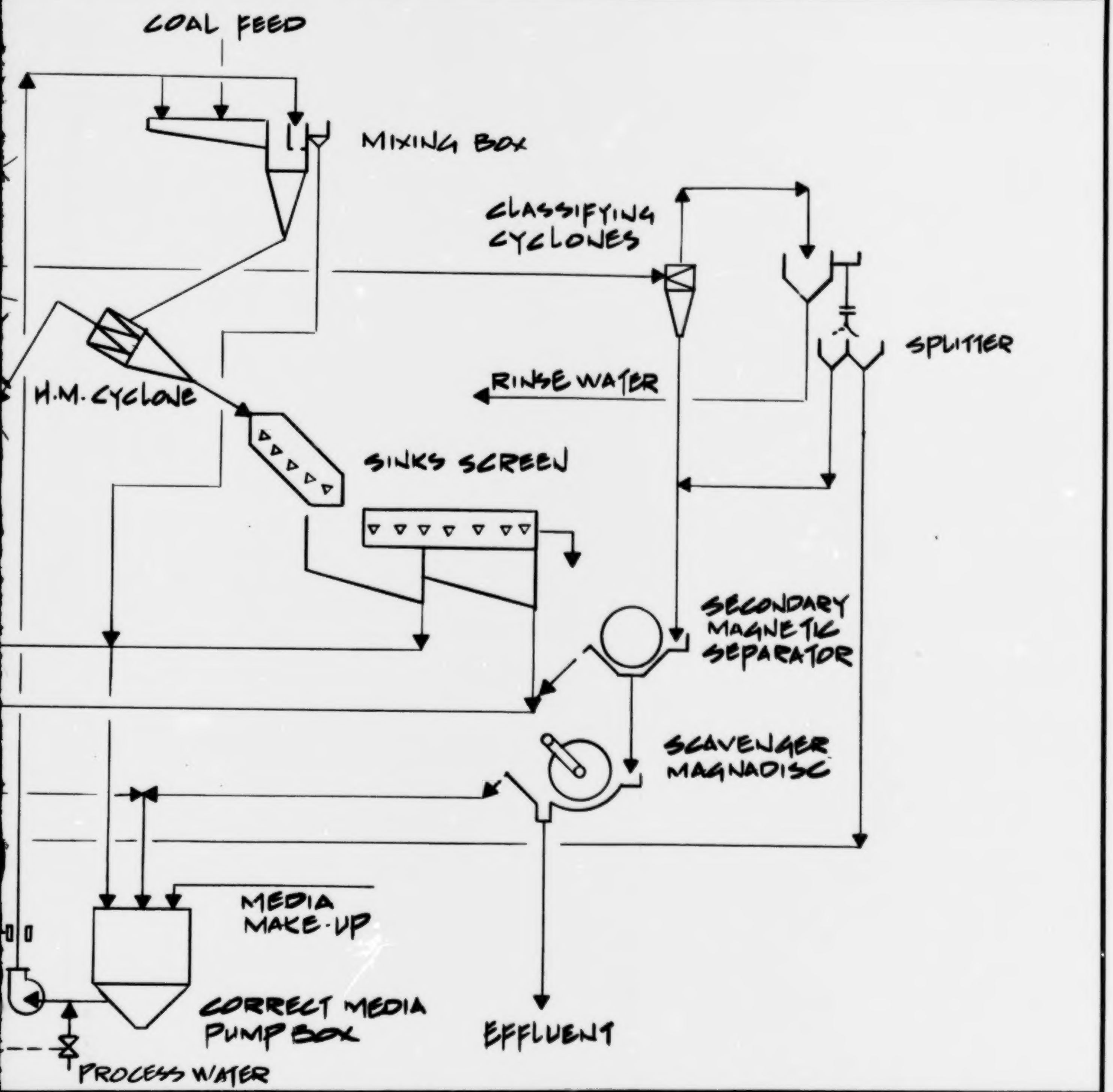
GRAVITY-FED HEAVY MEDIA CYCLONE SYSTEM SHOWING ALTERNATIVE POSITIONS FOR DENSITY GAUGE

SHEET No.	CONT. ON	DWG. No.	REV. No.
		FIGURE 3.11	


H.M.
FLOATS SCREEN
PRIMARY MAGNETIC SEPARATOR
DENSITY GAUGE
DILUTE MEDIA PUMPBOX
PR

REV.	ISSUED FOR	DATE	APPVD.	No.	DATE	REVISION

BCIL 88978-K.E.


COAL FEED
MIXING BOX
CLASSIFYING CYCLONES
SPLITTER
RINSE WATER
H.M. CYCLONE
SINKS SCREEN
SECONDARY MAGNETIC SEPARATOR
SCAVENGER MAGNADISC
MEDIA MAKE-UP
CORRECT MEDIA PUMP BOX
EFFLUENT
PROCESS WATER

CLIENT: SUPPLY & SERVICES CANADA
LOCATION: DEVON COAL RESEARCH CENTRE

KILBORN ENGINEERING (B.C.) LTD.

SECTION GENERAL	PROJECT No. 7814-15	AREA No.
DRAWN PL	CHECKED	EQMT. No.
DATE '86-3-27	APPROVED	PROJ. APPR.

TITLE

GRAVITY-FED HEAVY MEDIA CYCLONE SYSTEM WITH THIRD-STAGE SCAVENGER MAGNETIC SEPARATOR

SHEET No.	CONT. ON	DWG. No.	REV. No.
		FIGURE 3.12	

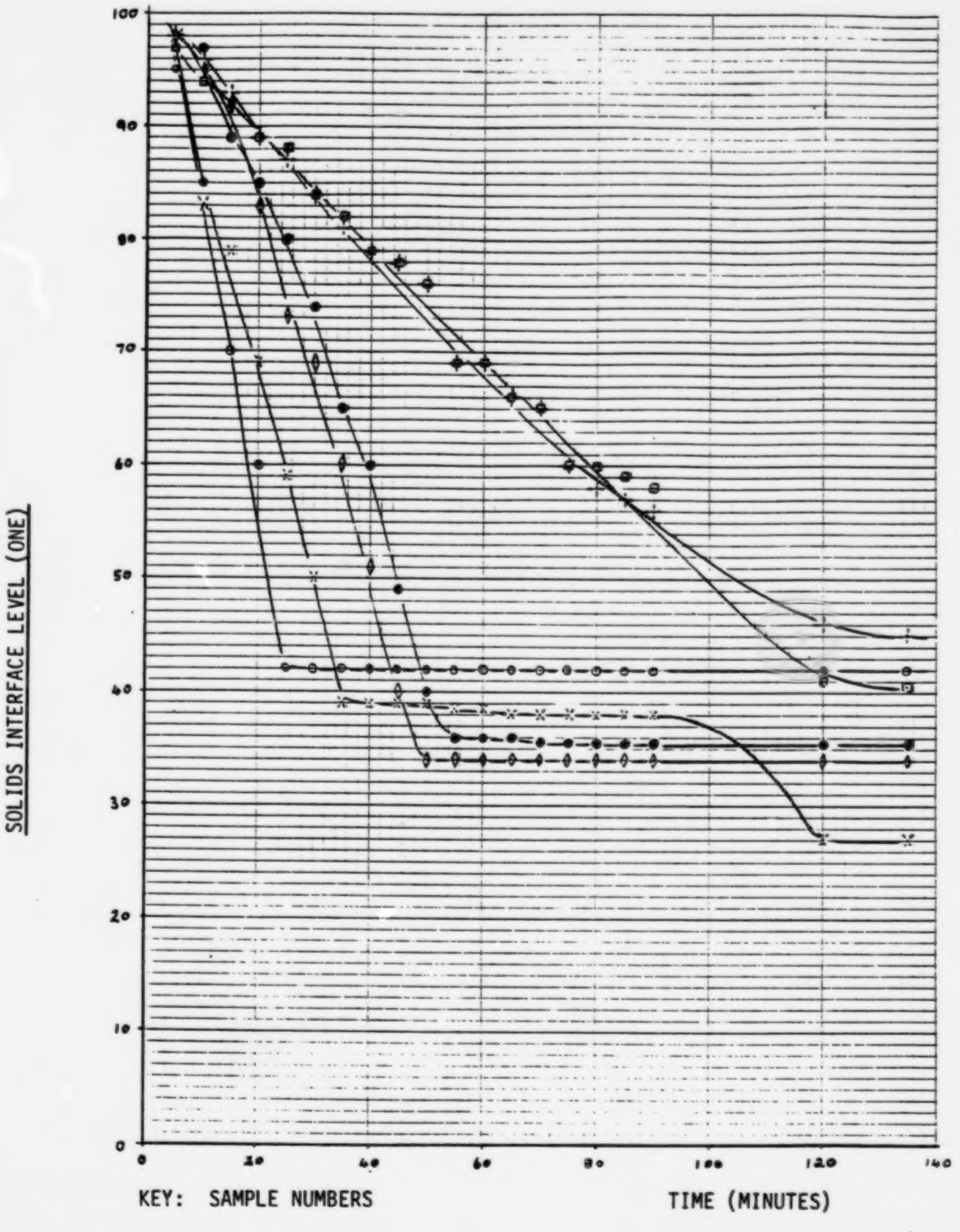


FIGURE 3-13

SETTLING RATES: De-magnetized sample for 1.6 R.D. Suspensions

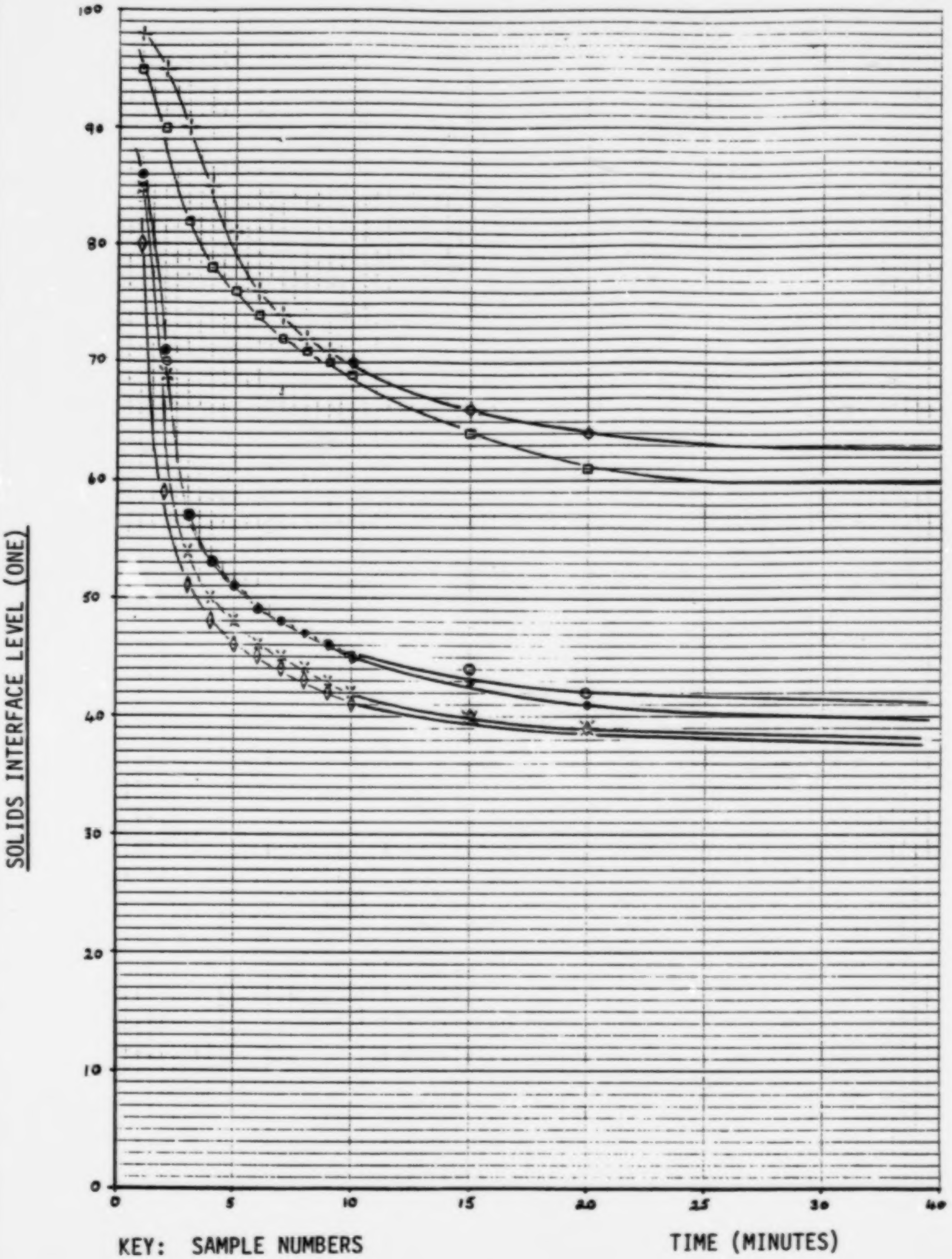


FIGURE 3-14
SETTLING RATES: Magnetic sample for 1.6 R.D. Suspensions

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - TRANSPORTATION AND STORAGE

					STORAGE AND HANDLING			
						STORAGE CAPACITY (TONNES)		
PLANT DESIGNATION	SUPPLIER	METHOD OF TRANSPORTATION	MODE OF TRANSPORTATION	SHIPMENTS PER ANNUM	STORAGE SYSTEM	AT PLANT SITE	MINIMUM INVENTORY	ANNUAL CONSUMPTION
Plant A	1.Craigmont Mines Ltd. 2.Dickenson Mines Ltd.	Rail Cars	Bulk	200 Railcars	Outside stockpile - transferred to charging bay - washed over Grizzly into sump and pumped to magnetite thickener	15,000	5,000	15,000
Plant B	NL Chemicals (New Jersey,USA)	Rail Cars (Flat Bottom Gondolas)	Bulk	2-3	Covered stockpile - transferred to mixing tank by overhead magnet and pumped to magnetite holding cone	3,000	1,000	5,000
Plant C	Craigmont Mines Ltd.	Road Trucking (Summer only)	Bulk	200	Outside stockpile on a concrete pad. Transported into the plant by front-end loader, to a 30 tonne stockpile beside the magnetite mixing hopper	15,000 - 20,000	3,000	6,000 - 7,000
Plant D	Craigmont Mines Ltd.	Road Truck (60 Ton)	Bulk	2	Inside stockpile (heated). No other details	2,000	5,000	1,750

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - TRANSPORTATION AND STORAGE

					STORAGE AND HANDLING			
						STORAGE CAPACITY (TONNES)		
PLANT DESIGNATION	SUPPLIER	METHOD OF TRANSPORTATION	MODE OF TRANSPORTATION	SHIPMENTS PER ANNUM	STORAGE SYSTEM	AT PLANT SITE	MINIMUM INVENTORY	ANNUAL CONSUMPTION
Plant E	Dickenson Mines	Rail Car	Bulk	-	Covered stockpile - added to overdense sump	4,00)	2,500	10,000
Plant F	1.Craigmont Mines Ltd. 2.Dickenson Mines (Bruce Lake) (Copper Cliff)	Rail Car to Sparwood off-loaded onto road trucks to plant	Bulk	-	Open air stockpile - transported to loading bay in plant by front-end loader	6,000	3,000	4,200
Plant G	Craigmont Mines	Road Truck	Bulk	100	Open stockpile - (10 ft. benches)	3,000	800	2-3,000
Plant H	M. Seven Industries (Craigmont)	Road Truck	Bulk	2	Covered stockpile - transferred by front-end loader to small stockpile in the plant. Mixed with water in agitator tank and pumped to magnetite thickener	4,500	600	1,600

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - TECHNICAL SPECIFICATIONS OF SUPPLIED MAGNETITE

	SPECIFICATION OF SUPPLIED MAGNETITE							QUALITY TESTING	
PLANT DESIGNATION	% MAGNETICS	% FE	% MINUS 325# (45 MICRONS)	% TOTAL MOISTURE	% NON-MAGNETICS	DENSITY G/CC	OTHER	TEST IN PLANT OR COMMERCIAL LAB	NUMBER OF TESTS PER YEAR
Plant A	>90	-	> 90	< 10	<10	-	-	Plant	12
Plant B	>95	70	80 - 85	< 10	< 5	4.9	Max.top Size: ¼"	Plant	2 - 6
Plant C	>90	-	90 ± 3	< 10	-	-	-	Both	< 10
Plant D	>90	-	90 ± 3	< 10	-	-	-	Neither	-
Plant E	>95 (Dry Basis)	69.3 (Dry Basis)	93	< 9.5	-	-	SiO_2 3.2% (Dry Basis)	Plant	Numerous (each rail car tested)
Plant F	>90 (Craigmont) >95 (Dickenson)		90 ± 3 (Craigmont) 93 (Dickenson)	< 10	-	-	-	Group Central Lab	3
Plant G	>90	N/A	90 ± 3	< 10	-	-	-	Plant	12 (1 Per Month)
Plant H	>90	>68.0	95	< 10	< 8.0	4.9	-	Plant	2

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - QUALITY TESTING (1)

ON-SITE TESTING

PLANT DESIGNATION	SIZING		MAGNETIC CONTENT		TOTAL MOISTURE		DENSITY		DEMAGNETIZATION	
	METHOD	SIEVE SIZE	METHOD	%	METHOD	%	METHOD	G/CC	METHOD	INDEX
Plant A	Wet screening (not demagnized before screening)	325 Mesh	Davis Tube	> 90	(probably oven drying or air drying)	<10	Pychometer (ASTM Standard)	-	-	-
Plant B	1.Screen to 325 mesh Alpine (air-jet screen)	325 Mesh	Magna - Chute	-	Air drying	-	Pycnometer (ASTM Standard)	-	n/a	n/a
	2.Below 325 Mesh by Bacho (air centrifuge - elutriator)	28 Micron to 1 micron range								
	3.Wet screening has been used in the past (not demagnized before any sizing method)	100 Mesh to 325 Mesh range								

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - QUALITY TESTING (1)

ON-SITE TESTING

PLANT DESIGNATION	SIZING		MAGNETIC CONTENT		TOTAL MOISTURE		DENSITY		DEMAGNETIZATION	
	METHOD	SIEVE SIZE	METHOD	%	METHOD	%	METHOD	G/CC	METHOD	INDEX
Plant C	Rarely done	-	Davis Tube	-	Oven drying (wt. loss)		Not done	-	Not done	-
Plant D	Not done		Not done		Not done		Not done	-	Not done	-
Plant E	Wet screening (no demagnetizing)	325	Davis Tube		Moisture oven at 105 degrees C (air dry method)		Not done	-	Not done	-
Plant F	Wet screening (no demagnetizing)	325	Davis Tube		Not done		-	2.8 (Bulk Density)	Not done	-
Plant G	Not done.	-	Not done.	-	Not done.		Not done.	-	Not Done	-
Plant H	Wet screening	50, 100, 200 and 325 mesh	Davis Tube	92-98	ASTM heat to 105 degrees C	<10.0	Not done	-	Not done	-

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - QUALITY TESTING

ON-SITE TESTING		OFF-SITE TESTING								
METHOD	SETTLING RATE	SIZING ANALYSIS	% MAGNETICS	% NON-MAGNETICS	% FE	% TOTAL MOISTURE	DENSITY	SETTLING RATE	EASE OF MAGNETIZATION	GENERAL COMMENTS
Plant A Not tested lab or plant	n/a	Supplier tests (no details given)	Supplier tests	Supplier tests	-	Supplier tests	-	-	-	Size and % magnetics used for contract
Plant B Not tested lab or plant	n/a									
Plant C Not done	-	Supplier tests at 100, 200, 325 mesh and 30, 22, 16, 10 and 7 micron	Supplier tests (Davis Tube)	Supplier tests	Supplier tests	Supplier tests	No testing	No testing	No testing	Insolubles, copper sulphurs
Plant D Not done	-	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded	No testing	No testing	No testing	Not recorded
Plant E F5 Index (not done routinely)		Not done	Not done	Not done	Not done	Not done	Not done	Not done	Not done	

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - QUALITY TESTING

ON-SITE TESTING		OFF-SITE TESTING								
SETTLING METHOD	SETTLING RATE	SIZING ANALYSIS	% MAGNETICS	% NON-MAGNETICS	% FE	% TOTAL MOISTURE	DENSITY	SETTLING RATE	EASE OF MAGNETIZATION	GENERAL COMMENTS
Plant F Not done	-	Supplier tests (Dickenson) Sized at 150 200 and 325 mesh	Supplier tests (Dickenson)	Supplier tests (Dickenson)	Not done	Supplier tests (Dickenson)	Supplier tests (Dickenson)	Not done	Not done	
		Typical results: +150: 0.8% 150-200: 1.4% 200-325: 4.0% -325 :93.8%	Typical result 97.3	Typical result 2.7		Typical result 6.2	Typical result 175	Not done	Not done	
Plant G Not Done	-	Supplier Tests Wet Screened at 325 mesh oversize oven dried and dry screened at 325 mesh	Supplier Tests on Monthly basis	Not done	Not done	Supplier Tests	Not Done	Not done	Not done	
Plant H Not done	-	10-51 micron range	92-98	Not done	Not done	Not done	Not done .	Not done	Not done	

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - CIRCUIT AND EQUIPMENT

PLANT DESIGNATION	MAGNETITE RECOVERY CIRCUIT DESCRIPTION	FLOWSHEET SUPPLIED	NEW EQUIPMENT	MAGNETITE RECOVERY EQUIPMENT DESCRIPTION
Plant A	Dilute media from rinse screens U/F pumped to dilute media cyclones (rinsing water cyclones). Cyclone U/F treated in two-stage magnetic separator. Overdense reports to thickener and is pumped to correct media. Suumps make-up magnetite is added to to thickener. Common recovery circuit for coarse and fine coal separators.	Yes	ASEA Magnadisc on test	Primary magnetic separators 1 x 30" x 72" - ERIEZ 1 x 30" x 96" - Indiana General Secondary magnetic separators 4 x 30" x 96" - ERIEZ 1 x 30" x 96" - Indiana General Scavenger magnetic separator - ASEA Dilute medium cyclones 10 x Roberts and Schaefer (D.S.M.)
Plant B	Dilute media from rinse screens U/F pumped to primary magnetic separators. Overdense reports to magnetite cone and is pumped via a splitter box to the heavy medium sumps for each section of the plant. Make-up magnetite is milled by ball mill and gravity fed to the overdense magnetite cone.	Yes	No	Primary magnetic separators 8 x 910 mm x 2700 mm - ERIEZ Secondary magnetic separators 8 x 910 mm x 2700 mm - ERIEZ

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - CIRCUIT AND EQUIPMENT

	MAGNETITE RECOVERY CIRCUIT		NEW EQUIPMENT	MAGNETITE RECOVERY EQUIPMENT DESCRIPTION
PLANT DESIGNATION	DESCRIPTION	FLOWSHEET SUPPLIED		
Plant C	Dilute media from rinse screens U/F pumped to two-stage magnetic separator (wet drum). The overdense reports to overdense sump and is pumped back to circuit the non-magnetic effluent.	No	No	Primary magnetic separators 3 x 36" x 96" single drum - Rapid 4 x 30" x 96" double drum - Stearns Secondary magnetic separators 3 x 36" x 96" single drum - Rapid
Plant D		No	No	Primary magnetic separators (two-stage) 5 x 30" x 90" - ERIEZ Scavenger magnetic sepearator - ASEA
Plant E	Dilute media from rinse screens U/F pumped to single stage magnetic separator (via headbox) overdense from separator reported to overdense sump. Non-magetics recycled to separator feed sump and portion gravity fed to dilute medium cyclones (20"). Cyclone O/F to rinse water and U/F gravity fed to secondary magnetic separator. The overdense reports to the overdense sump and the non-magnetics to the refuse thickener.	Yes	No	Primary magnetic separators 10 x 36" x 72" - ERIEZ Secondary magnetic separators 1 x 36" x 72" - ERIEZ Scavenger magnetic separators 1 x 36" x 72" - ERIEZ Dilute medium cyclones 10 x 20" D.S.M.

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - CIRCUIT AND EQUIPMENT

PLANT DESIGNATION	MAGNETITE RECOVERY CIRCUIT DESCRIPTION	FLOWSHEET SUPPLIED	NEW EQUIPMENT	MAGNETITE RECOVERY EQUIPMENT DESCRIPTION
Plant F	Dilute media from rinse screens U/F pumped to double stage separators. Overdense reports to magnetite thickener. Non-magnetics report to refuse thickener. Scavenger Magnadisc on refuse thickener.U/F	No	No	Primary magnetic separators (double drums) 3 - Stearns Scavenger - ASEA Magnadisc (16 discs)
Plant G	Dilute medium from rinse screens U/F (plus Clean Coal Centrate) reports to double drum separators. The overdense reports to the correct medium tank. Non-magnetics returned to circuit.	No.	No	Primary magnetic separators 4 x 36" Dings
Plant H	Dilute media from rinse screens U/F pumped to double stage magnetic separators. The overdense reports to the magnetite thickener and is pumped to the correct medium tank. The non-magnetics report to the dilute medium cyclones.	No	No	Primary magnetic separators 4 x 30" x 84" - ERIEZ

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - MAGNETITE CONSUMPTION

PLANT DESCRIPTION	DENSE MEDIUM CIRCUIT FEED RATE	MAGNETITE CONSUMPTION KG/TONNE FEED TO D/M CIRCUIT	METHOD USED TO DETERMINE MAGNETITE CONSUMPTION	AREAS OF POTENTIAL LOSS	MAGNETITE LOSSES PLAN TO REDUCE LOSSES	SCAVENGER	
						TYPE	LOCATION
Plant A	950 tph (400 vessels) (450 cyclones)	5.5 - 6.6	1. Monthly survey of stockpile. Compare monthly consumption with coal processed 2. Weight of magnetite delivered to plant from stockpile, compared to monthly coal processed	Clean coal drain and rinse screen (vessel)	Additional magnetic separator under investagtion	ASEA Magna-disc	Tailings Thickener U/F
Plant B		3 - 4	1. Comparison of bulk weight of magnetite consumed against coal processed. 2. Sample rinse screen products and magnetic separator effluents and calculate losses throughout the plant	Thickener underflow	Replacing existing separator with larger capacity	-	-
Plant C	600 - 800 (wet)	1.5 - 1.8 (assume 70% offered to dense-medium circuits and 70% overall yield of clean coal)	1. Comparison of bulk weight of magnetite consumed (loader-bucket count) again clean coal produced. 2. Periodic inventory survey of inside and outside stockpile and comparison made wit clean coal produced. 3. Magnetic surveys conducted in plant; adhering magnetite on products and magnetic separator losses	Magnetic separator tailings	No	-	-

DEPT. SUPPLY AND SERVICES - MAGNETITE STUDY

SUMMARY OF SURVEY DATA - MAGNETITE CONSUMPTION

PLANT DESCRIPTION	DENSE MEDIUM CIRCUIT FEED RATE	MAGNETITE CONSUMPTION LBS/TONNE FEED TO D/M CIRCUIT	METHOD USED TO DETERMINE MAGNETITE CONSUMPTION	AREAS OF POTENTIAL LOSS	MAGNETITE LOSSES PLAN TO REDUCE LOSSES	SCAVENGER TYPE	SCAVENGER LOCATION
Plant D	320	1.3	1. Comparison of bulk weight of magnetite charged)on a shift basis) with tons of coal processed. 2. Monthly consumption and inventory survey made against coal processed.	Magnetic separator tailings (refuse circuit)	1. Maintinj good operating conditions 2. Minimize spillage	ASEA Magnadisc	Refuse Thickener U/F
Plant E	-	Not reported	1. Periodic inventory survey of stockpile and comparison made against coal processed. 2. Shift as consumption calculated from density meter/flow meter.	General losses from magnetite recovery circuit	Upgrade screens sieves, and shower box	ERIEZ	Fine coal centrate and floor drainage passes to scavenger
Plant F	300	1.6	1. Monthly inventory survey of stockpile and comparison made against clean coal produced.	Magnetic separator effluent to thickener	Under review	ASEA Magnadisc	Underflow from refuse
Plant G	320-360	0.75-1.50	1. Comparison of bulk weight of magnetite charged (front end loader bucket count) compared to coal processed 2. Sample the rinse screen products and magnetite separator effluents and calculate losses throughout the plant	Magnetic separator non-magnetic tailings enters the non-magnetic fines circuit and is lost through the froth flotation circuit	Re-route magnetic separator non-magnetic tailings to magnetite thickener make-up line	None	-
Plant H	700	2.3	Monthly consumption and inventory survey (tonnage calculated from volume removed from stock) compared to coal processed.	Rinse screens (adhering to products) Piping leaks (occasional)	Maintain maintenance standards	None	-

4.0 MAGNETITE TESTING AND ANALYSIS

4.0 MAGNETITE TESTING AND ANALYSIS

4.1 SELECTION AND PREPARATION OF CANADIAN SAMPLES

Initially, it was proposed that suitable sources of magnetite for testing would be:

(a) Current producers;
(b) Potential suppliers;
(c) Innovative Sources (from fly ash).

A provisional list of potential sample sources was compiled and details of each supplier were obtained. Samples were then requested from these suppliers, and the following samples were received:

(a) Craigmont (British Columbia) - Ready to use for heavy medium;

(b) Island Copper (British Columbia) - Very fine, but low in magnetics;

(c) Texada Island (British Columbia) - Slightly coarse, requiring milling;

(d) Sherman Mines (Ontario) - Ready to use for heavy medium;

(e) Tawahus (New York) - Ready to use for heavy medium;

(f) Riess Viking (U.S.A.) - Ready to use for heavy medium;

(g) Whitehorse (Yukon) - Very fine, but low in magnetics;

(h) Cassiar Mining (British Columbia) - Coarse, requiring both milling and upgrading;

(i) Platinex (Tullameen, British Columbia) - Coarse, requiring both milling and upgrading;

(j) Iron Hill (British Columbia) - Very coarse, requiring crushing, milling and upgrading;

(k) Falcon (British Columbia) - Very coarse, requiring crushing, milling and upgrading.

No sample of fly-ash derived material was obtained although work is proposed in New Brunswick in this field. This work will commence shortly, and when sample material becomes available, a series of tests will probably be conducted that will be similar to those carried out for this Project. ECRL will be contacted when sample material becomes available.

A cross section of suppliers was required, and six were selected based mainly on the criterion that the company be in the position of being capable of supplying magnetite to the Canadian Coal Industry. These six selected samples were submitted to Chemex Labs Limited (Chemex) analysis.

Following inspection of the samples, it was observed that five of the samples could be used without further milling. One sample had to be wet milled to plus 95 percent below 325 mesh.

4.2 TEST AND ANALYTICAL WORK

Initially, it was proposed to base much of the preliminary test work on South African (Mintek 1984) recommendations, i.e.:

Size Analysis	- Sieve Range - wet screen at 100, 50 and 25 microns; - Subsieve Range - Warman Cyclosizer method.
Magnetics Content	- Standardized Davis Tube method; or - Standardized method for Magnetic Chute.

Chemical Analysis (Not mentioned in the Mintek Report) [Including Fe] - Volumetric;
- Inductively Coupled Plasma.

Moisture - Evaporation.

Medium Stability - F5 Index.

Demagnetization - Simon-Carves method.

Magnetic Susceptibility - Satmagan Apparatus.

Following receipt of the draft ISO 8833 Standard and further discussions, it was agreed between Kilborn and Chemex that the components of the test program would be based on ISO Standards were possible. This was subsequently confirmed in a Project meeting with the Scientific Authority. The following methods were adopted:

(a) Physical Properties

Relative Density - Determined by density jar method (Chemex);
Magnetics Content - Sedimentometer (EMR, CANMET);
Size Analysis - Test Sieves and Warman Cyclosizer (ACIRL Australia);
Ease of Demagnetization and Stability
Settling Tests - Simon-Carves method (Chemex).

(b) Mineralogical Properties

Iron Content - Total Iron by ISO 2597 (Chemex);
- Ferrous Iron by ISO 2597 (Chemex);

Chemical Analysis - Inductively Coupled Plasma (Chemex).

(c) Fundamental Magnetic Properties

Magnetic Susceptibility and Coercive Force - Magnetometer method (ACIRL)

The above analyses would then form the basis for a Canadian Code of Practice for magnetite testing and would be similar to that proposed for the draft ISO Standard, i.e.:

- Part 1 - Basic (Simple) Analytical Tests

  Fundamental tests necessary for assessing the quality of heavy media magnetite, i.e. moisture content, relative density, size distribution, magnetics content, iron content, settling characteristics and chemical analysis.

- Part 2 - Detailed (Specialized) Analytical Work

  Specialized tests, i.e. magnetic properties (susceptibility, remanance, coercive force, etc.), grinding properties, rheological characteristics, etc.

Following review of the analytical procedures and results, it was agreed that the preparation/analytical content for the Proposed Canadian Code of Practice should be:

(a) Preparation of the sample would be in accordance with the ISO Draft Standard No. ISO 8833.

(b) Analytical work on 'known' sources (i.e. currently used in plant) would comprise:

- Density (by wet Pycnometer method);
- Magnetics Content (by Magnetic Chute);
- Moisture (by Oven Evaporation);
- Settling Test (by Czechoslovakian method) - see Appendix 'C';
- Size Analysis (by ISO method involving fine sieves and Warman Cyclosizer);
- Total Iron and Ferrous Iron Content - ISO method.

(c) Analytical work on 'new' sources would comprise:

- Magnetic Properties (ACIRL method);
- Sulphur Content;
- Viscometric Tests.

4.3 TEST AND ANALYTICAL RESULTS

4.3.1 Chemex Test Program

The following paragraphs give a summary of the results obtained by Chemex. A copy of the detailed report by Chemex is included in Appendix 'A':

(a) Sample Preparation

Six samples were submitted to Chemex: five samples were fine magnetite powders, and one sample contained coarser material and had to be repulverized to minus 200 mesh. All samples were wet screened at 325 mesh (45 microns), and the minus 45 micron fraction repeatedly passed over a Simcar chute magnetic separator. The magnetic portion was retained in a separate beaker, and the procedure repeated until the entire sample had passed the separator. The procedure was repeated a second time. The non-magnetic tailings were then washed over the separator and the magnetic fraction added to the magnetic concentrate. The tailings obtained were discarded. Drying was done in a low temperature drying oven to minimize caking and oxidation of the magnetite. The dried samples were then screened to minus 200 mesh, homogenized and placed in air-tight bottles.

(b) Particle Size and Magnetic Content

Sample No.	% Moisture (As Received)	% -325 Mesh	% Magnetics
1	5.1	89.94	95.80
2	21.4	90.14	96.09
3	0.06	0.24	*
4	0.03	77.38	98.37
5	0.02	91.35	98.99
6	0.03	60.68	95.98

* Not sufficient minus 325 mesh for magnetic separation.

(c) Relative Density

A density bottle or water pycnometer method was used for relative density measurement:

Sample No.	Density at 25°C (gms/cc)
1	4.96
2	4.63
3	4.43
4	4.87
5	5.06
6	4.96

(d) Settling Rates

The calibrated cylinder method was used on magnetic and demagnetized samples:

	Sample No. (Magnetic Sample For 1.6 S.G. Suspension)					
Time (Mins.)	1 (ml)	2 (ml)	3 (ml)	4 (ml)	5 (ml)	6 (ml)
1	14	2	5	20	15	15
2	29	5	10	41	31	30
3	43	10	18	49	46	43
4	47	15	22	52	50	47
5	49	19	24	54	52	49
6	51	24	26	55	54	51
7	52	26	28	56	55	52
8	53	28	29	57	56	53
9	54	29	30	58	57	54
10	55	30	31	59	58	55
15	57	34	36	60	60	56
20	59	36	39	61	61	58
16 (Hrs.)	61	55	60	63	63	60

	Sample No. (Demagnetized Sample For 1.6 S.G. Suspension)					
Time (Mins.)	1 (ml)	2 (ml)	3 (ml)	4 (ml)	5 (ml)	6 (ml)
5	2	2	3	2	2	5
10	3	4	6	5	17	15
15	11	7	8	12	21	30
20	15	11	11	17	31	40
25	20	13	12	27	41	58
30	26	16	16	31	50	58
35	35	19	18	40	61	58
40	40	21	21	49	61	58
45	51	22	22	60	61	58
50	60	24	24	66	61	58

(Cont'd)

Time (Mins.)	Sample No. (Demagnetized Sample For 1.6 S.G. Suspension) 1 (ml)	2 (ml)	3 (ml)	4 (ml)	5 (ml)	6 (ml)
55	64	31	31	66	61.5	58
60	64	31	31	66	61.5	58
65	64	34	34	66	62	58
70	64.5	35	35	66	62	58
75	64.5	40	40	66	62	58
80	64.5	42	40	66	62	58
85	64.5	43	41	66	62	58
90	64.5	44	42	66	62	58
120	64.5	54	59	66	73	58
135	64.5	55	59.5	66	73	58

These results are illustrated graphically in Figures 3-13 and 3-14 which give settling curves for demagnetized and magnetized samples respectively.

(e) Chemical Analysis

Sample No.	% Fe_2O_3	% FeO	% SiO_2	% Al_2O_3	% Ca
1	66.76	29.08	2.31	0.34	0.15
2	60.68	28.00	6.15	1.44	<0.01
3	57.46	26.33	4.48	1.83	1.08
4	69.00	27.37	2.66	<0.01	<0.01
5	67.92	30.20	1.47	<0.01	<0.01
6	65.64	28.89	1.57	<0.01	<0.01

Sample No.	% MgO	% MnO	% TiO_2	% Cr_2O_3	% V_2O_5
1	0.45	0.015	0.053	0.012	0.030
2	0.41	0.075	0.537	0.130	0.096
3	2.67	0.250	2.75	0.229	0.391
4	0.35	0.009	<0.005	0.009	<0.005
5	0.23	0.087	<0.005	0.015	0.009
6	2.44	0.267	0.043	0.025	0.020

Sample No.	P_2O_5	% S
1	<0.01	0.02
2	<0.01	0.08
3	<0.01	0.01
4	<0.01	0.01
5	<0.01	<0.01
6	<0.01	0.05

4.3.2 Australian Coal Industry Research Laboratories Ltd. (ACIRL) Test Program

Six samples of minus 45 micron magnetite as prepared by Chemex were dispatched to the ACIRL. The samples had been magnetically upgraded as described in Section 4.3.1, and the percent magnetics of each sample is shown in the table in Section 4.3.1(a). Five of the samples weighed 400 grams and one sample was 200 grams.

The six samples were subdivided and dried for two hours at 105°C. The samples were then tested as follows:

(a) Size Analysis - Wet screening at 53, 45 and 38 microns; minus 38 micron sized by Warman Cyclosizer.

(b) Magnetic Quality - Tests carried out on the 45 by 38 micron size fraction. Properties assessed were: susceptibility at 30 oersteds; susceptibility at 800 oersteds, saturation moment and coercive force.

The results obtained are summarized as follows, but full details may be obtained from Appendix 'B':

(a) Size Analysis

Sample No.	% +0.038 mm	% -0.006 mm
1	1.0	20.6
2	0.3	39.3
3	0.8	32.6
4	5.7	15.5
5	1.9	16.1
6	5.9	22.3
Steetley Ultra-fine (Australian Magnetite)	11.0	18.3

The Steetley Ultra-fine sample was included for comparison purposes. It is the Australian grade with the finest size. From the results, it is noted that Sample No. 2 and Sample No. 3 contained considerably more minus 0.006 millimetres magnetite than required for normal coal preparation plant operations, while the size distribution of the other four samples approximated the current industrial standard for heavy media grade magnetite.

(b) Intrinsic Magnetic Properties

	Susceptibility At			
Sample No.	30 Oe (emu/g)	800 Oe (emu/g)	Saturation Moment (emu/g)	Coercive Force (Oe)
1	0.040	0.050	81	33
2	0.010	0.030	41	65
3	0.040	0.050	79	63
4	0.040	0.060	82	36
5	0.050	0.060	89	20
6	0.050	0.060	87	25
Australian Magnetite	>0.040	>0.050	80	<50

Compared to the Australian Standard, it can be seen that Sample Nos. 1, 4, 5 and 6 exhibited the intrinsic magnetic properties suitable for use as a heavy media in coal preparation plants. Sample No. 2 was totally unsatisfactory as a heavy media, and Sample No. 3 exhibited intermediate properties. The purity of Sample No. 2 appeared to be low, and from the low saturation moment and the high coercive force renders the magnetite unacceptable unless demagnetizing coils are used.

4.4 PROPOSED WORKING STANDARDS

4.4.1 Code of Practice

A major objective for conducting the test and analytical work on the six selected samples of magnetite, was to utilize the results obtained and review the methods used, in order to propose a Code of Practice for Canadian coal preparation plants.

Following review of analytical procedures and results, it was decided by Kilborn and Chemex, and later endorsed by the Scientific Authority, that the Code of Practice proposed would include the following principal determinations:

(a) Relative Density;
(b) Magnetics Content;
(c) Moisture Content;
(d) Settling Characteristics;
(e) Size Distribution;
(f) Total Iron and Ferrous Iron Content.

The above determinations would usually be conducted with samples obtained from each consignment delivered by a regular supplier. For new or potential sources of supply, especially those which have not formerly been used for heavy media applications, a more specialized program would be necessary. This would comprise the previous determinations together with some or all of the following:

(g) Magnetic Properties, as indicated by:

- Initial Susceptibility;
- Susceptibility at 800 oersteds;
- Saturation Moment; and
- Coercive Force;

(h) Chemical Content, in particular:

SiO_2, Al_2O_3, TiO_2, S, P, Cu, in addition to Fe and Fe_3O_4;

(i) Mineralogical Content;

(j) Viscosity of Prepared Suspensions.

Because of the specialized nature of these tests, it may be advisable to have them carried out by experienced analysts. Such facilities are available in Canada in several research institutes, universities and commercial laboratories. In some cases, highly specialized equipment is required, for example, in carrying out viscometric measurements.

4.4.2 Test Methods

Based upon the findings of the Survey of Magnetite described in the Report, Part I of this Project, and taking into consideration the test and analytical work carried out by Chemex and ACIRL, the following methods are recommended for the proposed Code of Practice:

(a) Relative Density

In compliance with the method suggested by ISO 8833, relative density should be determined using the wet pycnometer (relative density bottle) method in which the volume of liquid is displaced by a known mass of sample.

(b) Magnetics Content

The use of a magnetic chute is recommended for the determination of magnetics content. Other alternatives, such as the Davis Tube are acceptable for obtaining a measurement of magnetics content providing that a standardized method is employed.

The magnetic chute is inexpensive to obtain, simple to operate, has fixed magnetic field strength (permanent ceramic magnets), and can be employed for a multiple pass procedure to ensure total recovery of magnetic material. It was found by Chemex that normally two passes of the test sample are sufficient to recover the total magnetics content. The method for preparing and carrying out a test with a magnetic chute is very similar to that described for the ISO 8833 test method and, if preferred, this method can be adopted as the best alternative to the magnetic chute.

(c) Moisture Content

In compliance with the method suggested by ISO 8833, total moisture content can be determined either directly or in two stages, where the free moisture and air-dried moisture contents are separately determined. The latter method is, however, mainly applicable to large quantities.

Test portions of one kilogram or 100 grams (depending upon which stage is selected) are dried in a laboratory air-oven maintained at between 105°C and 110°C.

(d) Settling Characteristics

The ISO 8833 does not provide explicit instructions for the determination of the settling characteristics of magnetite suspension, but Kilborn believes that such data are of great value in evaluating the fundamental magnetic properties of a particular source of magnetite. They also provide a useful indication of the relative behaviour of magnetized and demagnetized medium as well as the ease with which the magnetite can be demagnetized.

During the test program, Chemex employed a method suggested by Simon-Carves. Subsequent to this work, information regarding a method employed in Czechoslovakia and Poland has been obtained. This method is believed to be simpler and more reliable than the Simon-Carves method, and for these reasons it is recommended for use in Canada. See Appendix 'C'.

(e) Size Distribution

In compliance with the method suggested by ISO 8833, the determination of the particle size distribution of heavy media grade magnetite should be carried out using a combination of test sieves and a sub-sieve centrifugal classifier. In the context of this standard, 'sub-sieve' implies mean particle sizes below 38 microns. The sieve analysis should comply with ISO 2591 and be conducted wet. The sub-sieve analysis is also best conducted wet, using a Warman Cyclosizer or equivalent centrifugal method. Sedimentation and evaluation methods are prone to the effects of magnetically induced agglomeration. Coulter-Counter instruments are similarly effected.

(f) Total Iron and Ferrous Iron Content

In compliance with ISO 8833, the determination of total iron and ferrous iron content should be the methods specified in ISO 2597 (Method 1b).

4.4.3 Sampling and Sample Preparation

Sampling of bulk (dry) magnetite should be carried out in accordance with the general recommendations of ISO 3081 which specifies the procedures for taking samples of iron-ore concentrates.

Sample preparation methods, also specified in ISO 3081, should be employed in obtaining sample material for analysis by the foregoing methods. The mass of sample required for each of these tests should be that specified in ISO 3083. Under normal circumstances, a single sample of one kilogram will adequately cover the analytical requirements described earlier. Sample division to obtain test portions for a particular analytical test should be carried out using the increment division method specified in ISO 3083. Alternatively, sample division with small stainless steel (non-magnetic) riffle dividers or other similar equipment may be used provided that these methods can be shown to be free of significant bias.

4.5 PROPOSED RESEARCH WORK

The main area which requires further research work is in the determination of the rheological properties of magnetite suspensions.

The Literature Survey, conducted as Part I of this Project, established that similar emphasis is being placed on work in this area in most other major coal producing countries, i.e.

West Germany, United States, Australia, and South Africa in particular. Two main avenues are being investigated:

(a) Medium viscosity relating to particle size analysis, fundamental magnetic properties and the presence of non-magnetic materials such as clay minerals;
(b) Medium stability and its determination.

While the first avenue is being specifically directed towards sophisticated scientific investigations involving new viscometric methods, the area of medium stability is mainly concerned with obtaining a reliable method for quantifying the effect.

This Report mentions the F5 Index, Simon-Carves settling method, and the Czechoslovakian J-Index, all of which are very empirical and, therefore, prone in varying degrees to operator bias. Although the latter method appears to be reliable and likely to be the least vulnerable to bias of those considered, there is undoubtedly still a need for a firm Canadian specification of a simple and reproducible method. All methods currently employed in determining medium stability should, therefore, be examined and carefully tested and evaluated prior to the selection of a suitable method for Canadian use.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 PLANT PROCEDURES AND EVALUATION

It is imporatant that in the operation of heavy media sections of a coal preparation plant, a full understanding of the following be obtained as quickly as possible:

(a) magnetite recovery and replacement circuits;
(b) limits of equipment performance and normal operating efficiency levels;
(c) methods and locations for sampling medium;
(d) control and instrumentation.

Detailed flowsheets should be available which provide up-to-date information regarding normal and maximum flowrates and balanced conditions at rated capacity.

Procedures should then be developed for a regular basis evaluation of equipment performance and magnetite loss. Kilborn recommends the following steps for these procedures:

1. Prepare a detailed flowsheet for each separate heavy media circuit and one overall flowsheet for the heavy media sections and media recovery and replacement circuit.

2. Select sample points and indicate them on the overall flowsheet.

3. Carry out an initial plant inspection noting all areas where loss may be occurring including any leaks or other areas of the media distribution system requiring repair. Proceed to repair these defects as quickly as possible.

4. Prepare a check list for regular testwork record purposes, and train plant/laboratory personnel in test and analytical methods required.

5. Commence regular testing and on the basis of results carry out circuit adjustments and remedial measures in a systematic manner.

6. During this program ensure that all personnel involved (in particular operations personnel) are kept informed and involved and set and revise targets for magnetite consumption as the work proceeds.

It may be more effective to monitor progress by employing a plant computer modelling program similar to those available from the following two sources:

(a) Coal Preparation Analysis Laboratory
Pittsburgh Energy Technology Center
U.S. Department of Energy
P.O. Box 10940
Pittsburgh, PA 15236
U.S. Department of Energy
P.O. Box 10940
Pittsburgh, PA 15236

Ref.: Coal Simulation Program for IBM.PC

Contact: Rand F. Batchelder
Chemical Engineer, Coal Preparation Division

(b) Department of Supply and Services, Ottawa

Ref.: "Bilmat" Programs for Plant Simulation for IBM.PC and Mainframe.

5.2 MAGNETITE TESTING AND ANALYSIS

With the introduction of the new ISO standard No. 8833, "The Testing of Magnetite for Use in Coal Preparation" later in 1986, Canadian heavy media plant operators and magnetite suppliers will have an ideal opportunity for adopting a standard approach to magnetite testing and analysis. Kilborn therefore recommends that the Scientific Authority assume the role of promoting this new standard throughout the Canadian users and suppliers as a first step in their continuing program of research work in this field.

The next step would be to supplement the standard, in the manner discussed earlier in this report, with firm specification of additional testing methods, in particular ones for assessment of medium stability and ease of demagnetization.

Finally, users and suppliers should be advised of the basic equipment and analytical needs to conduct the recommended testing methods. Also, a network of test centres able to carry out the more sophisticated work ie. viscosity, chemical and metallurgical and fundamental magnetic property determinations, should be prepared and circulated. These centres would then also be available for periodic 'round-robin' test programs to provide scrutiny of user and supplier test practices.

6.0 REFERENCES

SECTION 6.0 - REFERENCES

1. Draft Proposal ISO/DP 8833, 'The Testing of Magnetite for Use in Coal Preparation.' July 4, 1985, ISO Australian Secretariat.

2. L. Jonker, 'The Development of Standard Procedures for the Evaluation of Magnetite for Use in Heavy-Medium Separation.' MINTEK : Report No. M144. Council for Mineral Technology, South Africa, May 30, 1984.

3. 'Evaluation of Magnetic Heavy Media and Suspensions.' (Czech: Hodnoceni Magnetickych Zatezkavadel a Suspenzi.) The Coal Scientific Research Institute, Ostrava, Radvanica, Czechoslovakia, No. 44 1336.

4. C. C. Graham, 'The Application of Magnetite for Coal Preparation in Australia.' 1st Int'l. SME-AIME Fall Meeting, Honolulu, Hawaii, September 4-9, 1982.

5. Draft Proposal U2L 1408 H/4. National Coal Board (U. K.). Specification for Magnetite, 1985.

APPENDIX 'A'

TEST AND ANALYTICAL RESULTS OF

CHEMEX LABS LTD.

THE CHARACTERIZATION OF SIX REPRESENTATIVE MAGNETITE SAMPLES FOR HEAVY MEDIA COAL CLEANING

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February 19, 1986

A report submitted to Kilborn Engineering
in fulfillment of analytical requirements
for EMR:CANMET PROJECT 7814-15.

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1.0 INTRODUCTION

1.0 INTRODUCTION

The purpose of this study was to collect and characterize magnetite samples from six suppliers or potential suppliers of magnetite media for use in the Canadian coal industry. Only six samples were studied in detail due to financial limitations.

The analytical procedures were designed to be simple and direct to form a basis for on site testing of magnetite concentrate and heavy media from the circuit.

The analytical work is part of a joint contract with Kilborn Engineering to EMR CANMET Edmonton Coal Research Laboratory. Part 1* of the report includes a broad survey of sources, supplies and usage of magnetite media as well as international specifications and standards for testing.

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* Characteristics of Canadian Magnetite Resources for Optimum Utilization of Coal Heavy Media Process

2.0 SUMMARY

2.0 SUMMARY

There are many potential sources of magnetite for use as heavy media reagent in the coal industry. However, at present few mines in Canada are able to produce large amounts of product meeting industry specifications.

In this study samples were upgraded by screening and magnetic separation to produce samples which could be compared on the same basis.

Physical and chemical tests to characterize and test magnetite can be simplified, enabling on site testing with a low capital cost in analytical equipment. Moisture content, particle sizing to 45 microns, magnetic content, density and iron content may be all that is required for routine testing.

The ISO Standard DP 8833 "Testing of Magnetite for Use in Coal Preparation" is soon to be published a will provide an International Standard for the industry.

3.0 COLLECTION OF SAMPLES

3.0 COLLECTION OF SAMPLES

Magnetite samples were received from 11 of the 13 companies contacted. From these, 6 were selected for the test program.

The criteria for selection was that a company be in production supplying magnetite product to the Canadian coal industry or in a research stage proving adequate tonnage. Also considered was geographic location, covering as much of Canada as possible. Magnetite recovered as a by product was of special interest. The samples selected are shown in Table 1 and a complete list of samples received is in Appendix A.

4.0 SAMPLE PREPARATION AND UPGRADING

4.0 SAMPLE PREPARATION AND UPGRADING

The samples were weighed, dried at 60 Deg. C. then reweighed to determine surface moisture. A small sample (1/8 of total weight) was split using a Jones Riffler and labelled "as received".

Five samples were wet screened on a vibrating table using a 325 mesh (45 micron) brass sieve. The sample 3, which was received as 1 cm material was first pulverized in a Bico Braun rotary pulverizer to pass 200 mesh, then wet screened as above.

The minus 45 micron fractions from all six samples were then upgraded using a Simcar Chute magnetic separator. Small portions of the sample were mixed with water and washed carefully over the magnetic separator. The magnetic portion was retained in a separate beaker and the procedure repeated until the entire sample had passed the separator. The procedure was repeated a second time.

The non-magnetic tailings were again washed over the separator and the magnetic fraction added to the magnetic concentrate. The tailings were then discarded.

Drying was done in a low temperature drying oven to minimize caking and oxidation of the magnetite. The dried sample was then screened to -200 mesh, rolled on a rolling mat to homogenzie and bottled.

This fraction was labelled "Minus 45 Micron Product".

5.0 PHYSICAL PROPERTIES "AS RECEIVED FRACTION"

5.0 PHYSICAL PROPERTIES "AS RECEIVED FRACTION"

1. Particle Size

A 50 gram sub-sample was wet screened on a vibrating 325 mesh (45 micron) brass sieve, washed with 5 liters of distilled water, dried, weighed and reported as percentage -325 mesh.

2. Magnetic content

The weighed -325 fraction from the particle sizing was washed 2X over the Simcar Chute, dried, weighed and reported as percentage magnetics.

This is shown in more detail in Appendix B.

The "as received" moisture, particle sizing and magnetic content are shown in Table 2.

TABLE 5.01

Moisture, Particle Size and Magnetic Content of "As Received" Fractions.

	Moisture %	-325 Mesh %	Magnetics %
Sample #1	5.1	89.9	95.80
Sample #2	21.4	99.5	96.09
Sample #3	0.06	0.24	*
Sample #4	0.03	87.0	98.37
Sample #5	0.02	93.9	98.99
Sample #6	0.03	64.9	95.98

*Non Sufficient - 325 Mesh for Magnetic Separation

6.0 PHYSICAL PROPERTIES

6.0 PHYSICAL PROPERTIES "Minus 45 Micron Product"

1. Particle Size and Magnetometer Test

Bottles containing 400 gm of the "-325 mesh product" were sent to Dr. Colin Graham, Manager - Coal Preparation, Australian Coal Industry Research Laboratories Ltd., Sydney, Australia.

Dr. Graham used a Warman Cyclosizer for sub sieve sizing. Magnetometer measurements were made on the -45 +38 micron fraction. Magnetic susceptibility, and coercive force were determined by this method and are shown in Tables 6.01 and 6.02.

2. Relative Density

A density bottle or water pychnometer method was used for relative density measurement. The procedure is described in detail in Appendix C and the results in Table 5.

3. Settling Rates - Calibrated Cylinder Method

Settling rates were determined by the calibrated cylinder method on magnetic and demagnetized samples. A suspension of 1.6 specific gravity was made in a 100 ml graduated cylinder. The stoppered cylinder was inverted 6X, placed on the bench and the settling rate measured with a stop watch.

A portion of the sample was demagnetized by heating to 750 Deg. C for 90 minutes, cooled, then analyzed as above.

The settling rates are shown in Tables 6 and 7 and a more detailed description of the method in Appendix D.

TABLE 6.01

RELATIVE DENSITY OF THE OF THE "MINUS 45 MICRON PRODUCT"

	DENSITY AT 25 DEG.C
Sample #1	4.96
Sample #2	4.63
Sample #3	4.43
Sample #4	4.87
Sample #5	5.06
Sample #6	4.96

7.0 CHEMICAL ANALYSIS - "MINUS 45 MICRON PRODUCT"

7.0 CHEMICAL ANALYSIS - "MINUS 45 MICRON PRODUCT"

a) Total Iron - Reference 1SO 2597

Total iron was determined using a sodium peroxide-sodium hydroxide fusion, hydrochloric acid leach, precipitation with ammonium hydroxide and dissolution in dilute hydrochloric acid. The ferric iron was reduced with stannous chloride and titrated against standardized potassium dichromate using diphenylamine sulphonate as an indicator.

b) Ferrous Iron - Reference ISO 2597

A 0.5 gram sub-sample was decomposed in hydrochloric acid in a nitrogen atmosphere. The ferrous iron was then titrated against potassium dichromate as above.

c) Total Silica

A 1 gram sample was fused in a sodium peroxide-sodium hydroxide flux, acidified with acetic acid, then analyzed by atomic absorption spectrophotometry (AAS) and reported as % SiO_2.

d) Sulphur

A 0.2 gram sub-sample was fused in a copper flux in an Induction Furnace. The SO_2 gas formed was dissolved in dilute hydrochloric acid, then titrated with potassium iodate solution using a starch indicator.

e) Multi-element Analysis

A 1 gram sample was decomposed in concentrated hydrochloric acid, diluted, then filtered into a volumetric flask. The residue was ashed, then decomposed in a perchloric acid - hydrochloric acid, then transferred into the 250 ml flask containing the original filtrate. The solution was then analyzed with a JY48 Inductively Coupled Plasma.

The values for Total Fe, FeO, SiO_2, Al_2O_3, CaO, MgO, MnO, TiO_2, Cr_2O_3, V_2O_5, P_2O_5 and S are listed in Table 8.

TABLE 6.02

SETTLING RATES - MAGNETIC SAMPLE FOR 1.6 S.G. SUSPENSIONS

TIME Minutes	SAMPLE #1 ml	SAMPLE #2 ml	SAMPLE #3 ml	SAMPLE #4 ml	SAMPLE #5 ml	SAMPLE #6 ml
1	14	2	5	20	15	1
2	29	5	10	41	31	30
3	43	10	18	49	46	43
4	47	15	22	52	50	47
5	49	19	24	54	52	49
6	51	24	26	55	54	51
7	52	26	28	56	55	52
8	53	28	29	57	56	53
9	54	29	30	58	57	54
10	55	30	31	59	58	55
15	57	34	36	60	60	56
20	59	36	39	61	61	58
16 hrs.	61	55	60	63	63	60

TABLE 6.03

SETTLING RATES - DEMAGNETIZED SAMPLE FOR 1.6 S.G. SUSPENSIONS

TIME Minutes	SAMPLE #1 ml	SAMPLE #2 ml	SAMPLE #3 ml	SAMPLE #4 ml	SAMPLE #5 ml	SAMPLE #6 ml
5	2	2	3	2	2	5
10	3	4	6	5	17	15
15	11	7	8	12	21	30
20	15	11	11	17	31	40
25	20	13	12	27	41	58
30	26	16	16	31	50	58
35	35	19	18	40	61	58
40	40	21	21	49	61	58
45	51	22	22	60	61	58
50	60	24	24	66	61	58
55	64	31	31	66	61.5	58
60	64	31	31	66	61.5	58
65	64	34	34	66	62	58
70	64.5	35	35	66	62	58
75	64.5	40	40	66	62	58
80	64.5	42	40	66	62	58
85	64.5	43	41	66	62	58
90	64.5	44	42	66	62	58
120	64.5	54	59	66	73	58
135	64.5	55	59.5	66	73	58

TABLE 7.01

CHEMICAL ANALYSIS OF MINUS 45 MICRON PRODUCT

Sample	% Fe203	%Fe 0	%Si02	%Al203	%Ca
SAMPLE #1	66.79	29.09	2.31	0.34	0.15
SAMPLE #2	60.83	28.07	6.17	1.44	<0.01
SAMPLE #3	57.59	26.39	4.49	1.83	1.08
SAMPLE #4	69.00	27.37	2.66	<0.01	<0.01
SAMPLE #5	67.92	30.20	1.47	<0.01	<0.01
SAMPLE #6	65.66	28.90	1.57	<0.01	<0.01

Sample	%MgO	%MnO	%Ti02	%Cr203	%V205
SAMPLE #1	0.45	0.015	0.053	0.012	0.030
SAMPLE #2	0.41	0.075	0.537	0.130	0.096
SAMPLE #3	2.68	0.250	2.76	0.229	0.391
SAMPLE #4	0.35	0.009	<0.005	0.009	<0.005
SAMPLE #5	0.23	0.087	<0.005	0.015	0.009
SAMPLE #6	2.44	0.267	0.043	0.025	0.020

Sample	%P205	%S
SAMPLE #1	<0.01	0.02
SAMPLE #2	<0.01	0.08
SAMPLE #3	<0.01	0.01
SAMPLE #4	<0.01	0.01
SAMPLE #5	<0.01	<0.01
SAMPLE #6	<0.01	0.05

8.0 CONCLUSIONS

8.0 CONCLUSIONS

The excellent response to the request for samples indicates a keen interest by mining companies to fill the projected requirements of magnetite media for use in the coal industry.

The 6 magnetite products chosen for this study are a small sampling of potential sources. These have however, shown that a good product can be produced with screening and magnetic separation.

Plant testing of magnetite feed and circuit media can be made simple and direct. Analysis for moisture, percentage iron, settling rates, magnetics, density and particle size at 45 microns can be done with inexpensive laboratory equipment.

More detailed analysis may be required to test new supplies of magnetite media. Sub-sieve sizing and total chemical analysis can be sent to larger research and commercial laboratories equipped with specialized instruments.

Standard procedures such as those mentioned in this study should be used for testing. The new ISO DP 8833 Standard "Testing of Magnetite for Use in Coal Preparation" is of particular interest.

APPENDIX A

Magnetite Samples Received

Company or Property	Location
Cassiar Mining Corporation	Cassiar, BC
Craigmont Mine	Merritt, BC
Falcon Iron Property	MacKenzie, BC
Iron River Property	Campbell River, BC
Island Copper Mine	Port Hardy, BC
Platinex Mining Corporation	Princeton, BC
Reiss Viking Corporation	Tazewell, West Virginia
Sherman Mine	Temagami, Ontario
Tawahus - National Lead & Chemical	Tawahus, New York
Texada Iron Mines	Gilles Bay, Texada Island, BC
Whitehorse Copper Mine	Whitehorse, Y.T.

APPENDIX B

Procedure for the Use of Magnetic Separator

1. Set the separator on a 20 Deg. angle with a catch beaker at the lower end.
2. Scoop about 10 gram increments of sample into a 250 ml beaker containing approximately 125 ml of water.
3. Swirl to mix, then gently decant the solution over the inclined separator from the higher level to the lower level.
4. Wash suspension slowly over separator with a stream of water.
5. Rinse the magnetite with water.
6. Remove the magnet from the separator and wash the magnetic concentrate into a 1000 ml beaker with a wash bottle.
7. Repeat until total of 50 grams of sample concentrated.
8. Repeat procedure on magnetic concentrate.
9. Repeat procedure on tailings and add this concentrate to concentrate from step 8.

APPENDIX C

Relative Density at 25 Degrees Centigrade

1. Record weight of pycnometer and cap
2. Add 10 grams of dry sample and record weight of pychnometer + cap + sample
3. Add 1 drop of photoflow, add deaerated water to cover sample
4. Evacuate 15 minutes in vacuum desicator
5. Centrifuge 5 minutes
6. Equilibrate in water bath 30 minutes at 25 +/- 0.1 deg. C
7. Stopper, dry, weigh immediately
8. Calibration of pychnometer
    - Half fill pychnometer with deaerated water
    - Evacuate 15 minutes in desicator
    - Centrifuge 5 minutes
    - Equilibrate 30 minutes

Calculations:

The relative density shall be calculated on a solids to distilled water basis at 25 Deg. C by the formula:

$$\text{Relative Density } \frac{\text{RD 25 Deg. C}}{\text{25 Deg. C}} = \frac{m2 - m1}{(m2-m1)-(m3-m5)} \times \frac{m5 - m1}{m4 - m1}$$

Where:
m1 is the mass of the density bottle and stopper (g)
m2 is the mass of the density bottle and stopper plus solids (g)
m3 is the mass of the density bottle and stopper plus solids, plus liquid used as test medium (g)
m4 is the mass of the density bottle and stopper plus distilled water (g)
m5 is the mass of the density bottle and stopper plus liquid used as test medium (g)

When distilled water only is used in the determination, m4 and m5 are synonymous and the above formula reduced to:

$$\frac{\text{RD 25 Deg. C}}{\text{25 Deg. C}} = \frac{m2 - m1}{(m2-m1) - (m3-m4)}$$

The reported result shall be the mean of duplicate determinations and be expressed to one place of decimal.

APPENDIX D

Settling Rates - Calibrated Cylinder Method

1. Prepare a slurry of relative density of 1.6 gm/cc
2. Place in a 100 ml graduated cylinder
3. Add 10 ml of 0.5 M calgon solution
4. Fill to 100 ml, stopper, then thoroughly agitate
5. Invert 6X and place on level surface
6. Immediately start stop watch
7. Remove stopper
8. Measure level of solid - liquid interface each minute
9. Plot level vs time
10. Demagnetize a portion of magnetite by heating at 750 deg. C for 1 hour. Leave furnace door open slightly for good air access.
11. Cool
12. Repeat settling rate test with demagnetized sample

APPENDIX 'B'

TEST AND ANALYTICAL RESULTS OF A.C.I.R.L.

ACIRL
COAL RESEARCH

AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.
INCORPORATED IN N.S.W.
REGISTERED OFFICE 14-30 DELHI ROAD, NORTH RYDE, N.S.W. 2113
TELEPHONE: 887 3777 TELEX: 27251

REPORT TO : Mr. D. Osborne,
Kilborn Engineering (B.C.) Ltd.
1380 Burrard Street,
Vancouver, British Columbia,
CANADA, V6Z 2B7

REPORT ON : Assessment of intrinsic magnetic properties and size distribution on six Canadian magnetites

REFERENCE : Telex No. 0030, January 22, 1986

PREPARED BY : C.C. Graham

REPORT NO : 09/1434

DATE : February 17, 1986

Graham
....
C.C. Graham
Manager - Coal Preparation

JUNCTION STREET, TELARAH, N.S.W., AUSTRALIA. TELEPHONE: (049) 32-8377, 32-8580
P.O. BOX 26, MAITLAND, N.S.W., 2320. TELEX: 72285

ACIRL
COAL RESEARCH

AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.
INCORPORATED IN N.S.W.
REGISTERED OFFICE 14-30 DELHI ROAD, NORTH RYDE, N.S.W. 2113
TELEPHONE: 887 3777 TELEX: 27251

REPORT TO :

KILBORN ENGINEERING (B.C.) LTD.

Assessment of Intrinsic Magnetic Properties and Size Distribution on Six Canadian Magnetites

REPORT NO:09/1434

JUNCTION STREET, TELARAH, N.S.W., AUSTRALIA. TELEPHONE: (049) 32-6377, 32-6999
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SUMMARY

Six samples of magnetite from Kilborn Engineering, Canada, were subjected to magnetometer and sizing tests, in order to evaluate the quality for use in dense medium coal preparation.

Analysis of the materials supplied, indicated that four of the samples exhibited the intrinsic magnetic properties currently required by the Australian coal preparation industry for dense medium coal preparation, but the Sample No. 2 and Sample No. 3 samples did not. These latter samples had been ground considerably finer than normal for coal preparation requirements, which could have influenced the results and retesting is advised.

Sample No. 1, Sample No. 4, Sample No. 5, and Sample No. 6 conformed to the specifications for both intrinsic magnetic properties and the size distribution used in coal preparation.

INTRODUCTION

Five 400g and one 200g samples of magnetite marked Sample No. 1, Sample No. 2, Sample No. 3, Sample No. 4, Sample No. 5 and Sample No. 6 were provided by Chemex Labs Ltd., North Vancouver to ACIRL for assessment of quality, and comparison with materials currently used for dense medium coal preparation in Australia.

TEST SCHEDULE

(a) Sampling

After drying in air under ambient conditions, the original magnetite specimens were sampled representatively by rotary sample division as referred to in the Australian Standard AS1676.

(b) Moisture

Portion of each air dried sample was dried in air at 105 degrees Celsius for 2 hours to obtain a fully dried sample for the magnetometer test.

(c) Size Analysis

Each sample was wet screened by hand using square mesh standard sieves at 0.053, 0.045 and 0.038mm. The minus 0.038mm portion was analysed by Warman Cyclosizer, and the two sizing analyses were then combined from which a Rosin Rammler Bennet plot was then produced by computer.

(d) Magnetic Quality

Magnetometer tests were carried out with the ACIRL vibrating sample magnetometer under standard conditions, on material sized by wet screening to minus 0.045mm plus 0.038mm. The properties assessed were : Susceptibility at 30 oersteds, Susceptibility at 800 oersteds, Saturation Moment and Coercive Force.

RESULTS

(a) Size Analyses

Appendices 1 to 12 show the combined wet screen and Warman Cyclosizer size analyses, together with the corresponding Rosin Rammler plot, for each shown in comparison with the finest of the Australian coal preparation size grades. From these, it will be noted that the Sample No. 2 and Sample No. 3 samples contained considerably more minus 0.005mm magnetite than required for normal coal preparation requirements, whilst the size distribution of the others approximated the industry requirements. In summary the results were as follows :

Magnetite Source	Percent + 0.038mm	Dry Basis - 0.006mm
Sample No. 1	1.0	20.6
Sample No. 2	0.3	39.3
Sample No. 3	0.8	32.6
Sample No. 4	5.7	15.5
Sample No. 5	1.9	16.1
Sample No. 6	5.9	22.3
Steetley Ultraline	11.0	18.3

(b) Intrinsic Magnetic Properties

Appendices 13 to 18 inclusive set out the results of these analyses.

In summary the results were :

	Susceptibility @		Saturation	Coercive
Magnetite Source	30 oersteds emu/g	800 oersteds emu/g	Moment emu/g	Force (oersteds
Sample No. 1	0.040	0.050	81	33
Sample No. 2	0.010	0.030	41	65
Sample No. 3	0.040	0.050	79	63
Sample No. 4	0.040	0.060	82	36
Sample No. 5	0.050	0.060	89	20
Sample No. 6	0.050	0.060	87	25
Australian Magnetite	>0.040	>0.050	>80	<50

Review of the results shows that samples 1, 4, 5 and 6 exhibited the intrinsic magnetic properties suitable for use in coal preparation dense medium.

Sample 2 was quite unsatisfasctory and Sample 3 exhibited intermediate properties. The purity of Sample 2 appeared to be low from the low saturation moment and the high coercive force renders the material unacceptable in this country, due to the general absence of demagnetising coils in Australian coal preparation plant magnetite recovery circuits.

APPENDIX 1

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 1

SIZE ANALYSIS

SIZE (millimetres)	FRACTIONAL % Retained	CUMULATIVE % Retained	CUMULATIVE % Passing
* 0.053	0	0	100
* 0.045	0	0	100
* 0.038	1.0	1.0	99.0
0.023	32.4	33.4	66.6
0.017	12.5	45.9	54.1
0.012	13.4	59.3	40.7
0.008	10.7	70.0	30.0
0.006	9.4	79.4	20.6

Analyses carried out using a Warman Cyclosizer unit except for those marked (*), which were carried out using Wet Sieve Analysis.

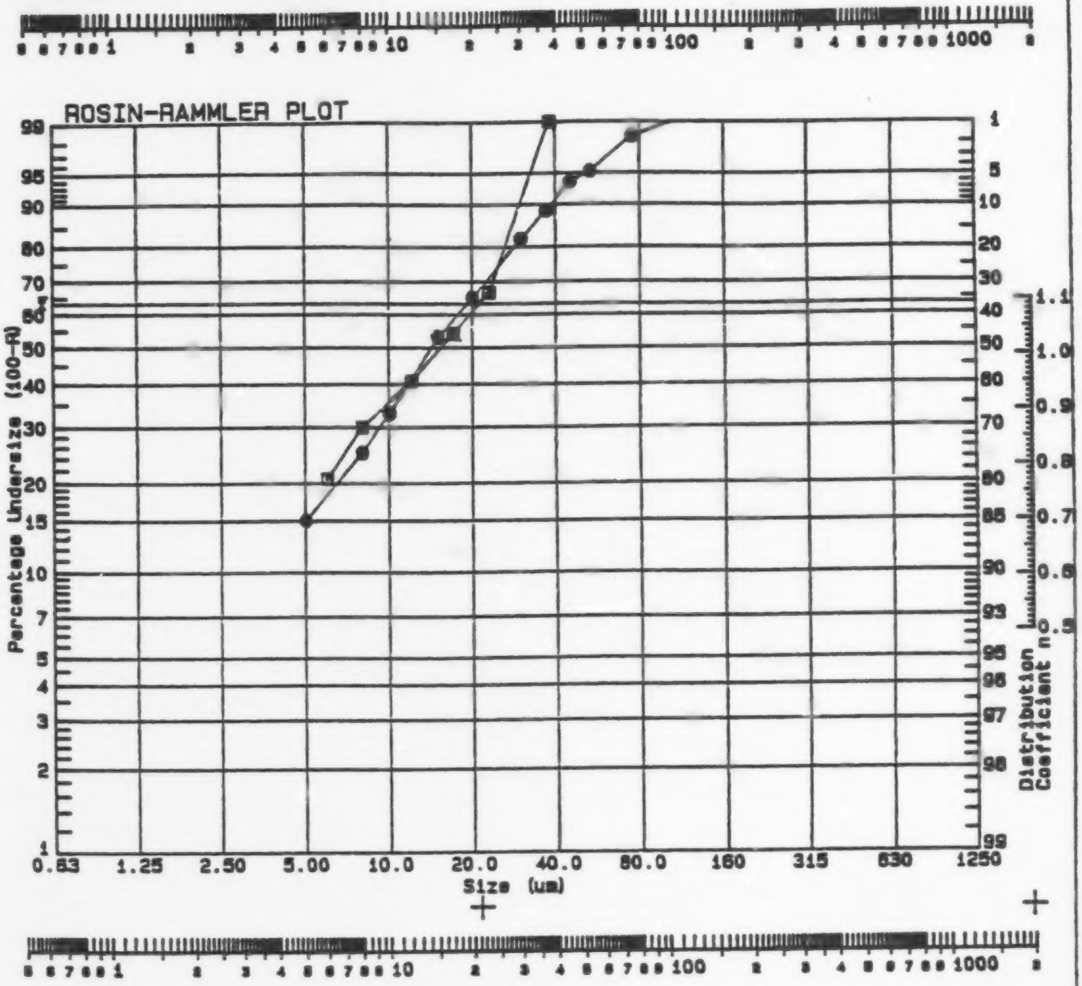
....
A. C. I. R. L.
Maitland Laboratory

APPENDIX 2

AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.

SIZE ANALYSIS

17-FEB-88



LEGEND

■ Kilborn Engineering: Sample No. 1 Size Analysis
● Steetley Ultrafine Magnetite

APPENDIX 3

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 2

SIZE ANALYSIS

SIZE (millimetres)	FRACTIONAL % Retained	CUMULATIVE % Retained	CUMULATIVE % Passing
* 0.053	0	0	100
* 0.045	0	0	100
* 0.038	0.3	0.3	99.7
0.023	2.2	2.5	97.5
0.017	5.3	7.8	92.2
0.012	17.3	25.1	74.9
0.008	22.3	47.4	52.6
0.006	13.3	60.7	39.3

Analyses carried out using a Warman Cyclosizer unit except for those marked (*), which were carried out using Wet Sieve Analysis.

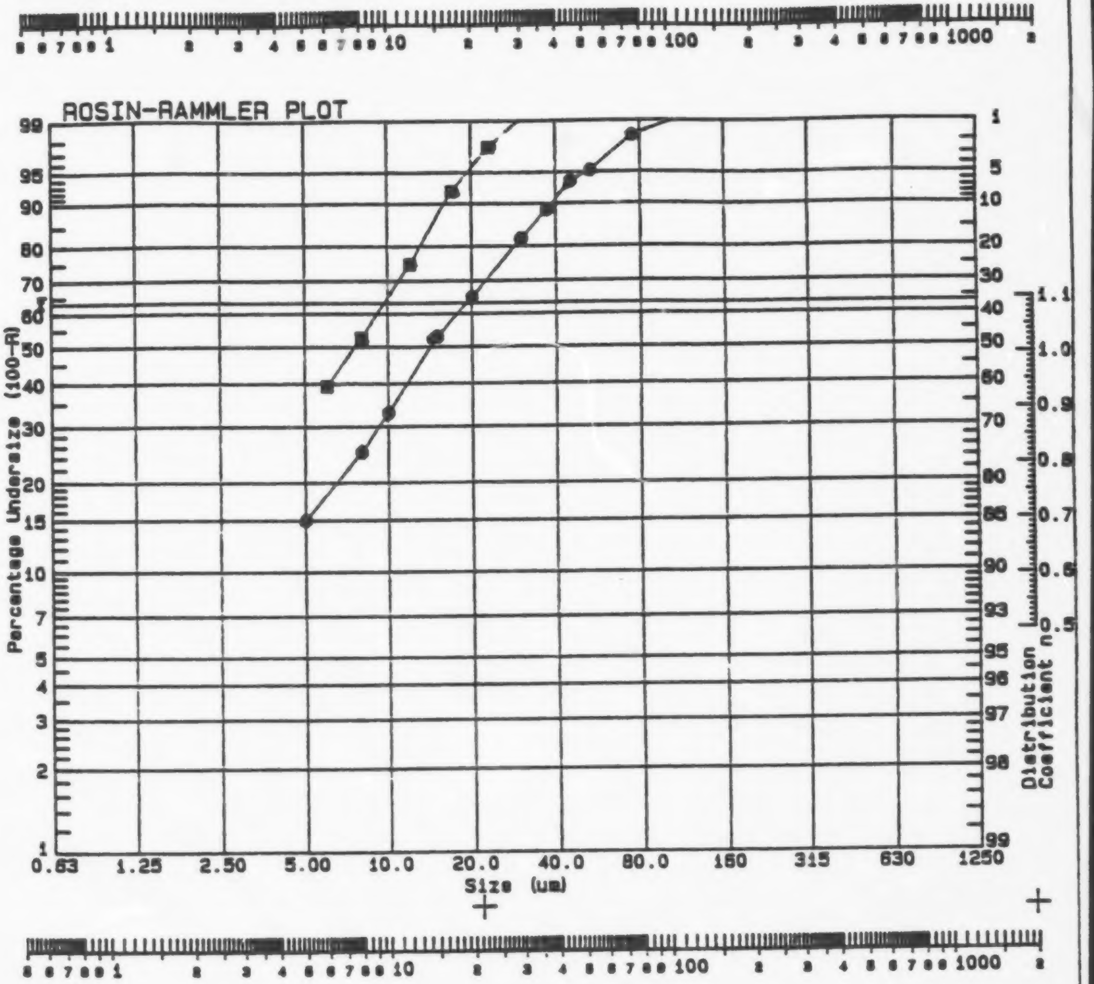
....
A. C. I. R. L.
Maitland Laboratory

APPENDIX 4

AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.

SIZE ANALYSIS

17-FEB-86



LEGEND

■ Kilbern Engineering: Sample No. 2 Size Analysis
● Steetley Ultrafine Magnetite

APPENDIX 5

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 3

SIZE ANALYSIS

SIZE (millimetres)	FRACTIONAL % Retained	CUMULATIVE % Retained	CUMULATIVE % Passing
* 0.053	0	0	100
* 0.045	0	0	100
* 0.038	0.8	0.8	99.2
0.023	18.1	18.9	81.1
0.017	11.7	30.6	69.4
0.012	15.3	45.9	54.1
0.008	13.3	59.2	40.8
0.006	8.2	67.4	32.6

Analyses carried out using a Warman Cyclosizer unit except for those marked (*), which were carried out using Wet Sieve Analysis.

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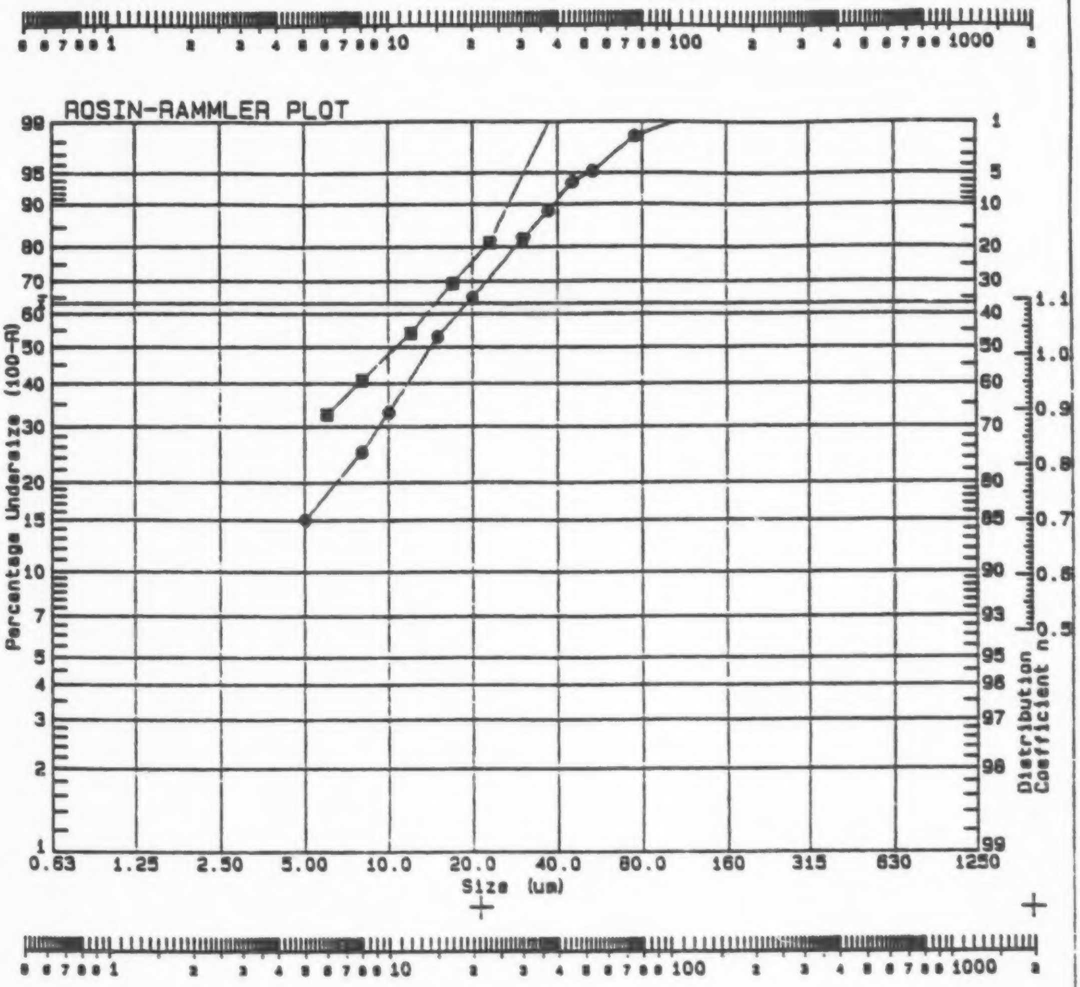
Maitland Laboratory

APPENDIX 6

AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.

SIZE ANALYSIS 17-FEB-88



LEGEND

■ Kilborn Engineering: Sample No. 3 Size Analysis
● Steetley Ultrafine Magnetite

APPENDIX 7

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 4

SIZE ANALYSIS

SIZE (millimetres)	FRACTIONAL %	CUMULATIVE %	
	Retained	Retained	Passing
* 0.053	0	0	100
* 0.045	0	0	100
* 0.038	5.7	5.7	94.3
0.023	35.0	40.7	59.3
0.017	14.2	54.9	45.1
0.012	14.3	69.2	30.8
0.008	10.1	79.3	20.7
0.006	5.2	84.5	15.5

Analyses carried out using a Warman Cyclosizer unit except for those marked (*), which were carried out using Wet Sieve Analysis.

....
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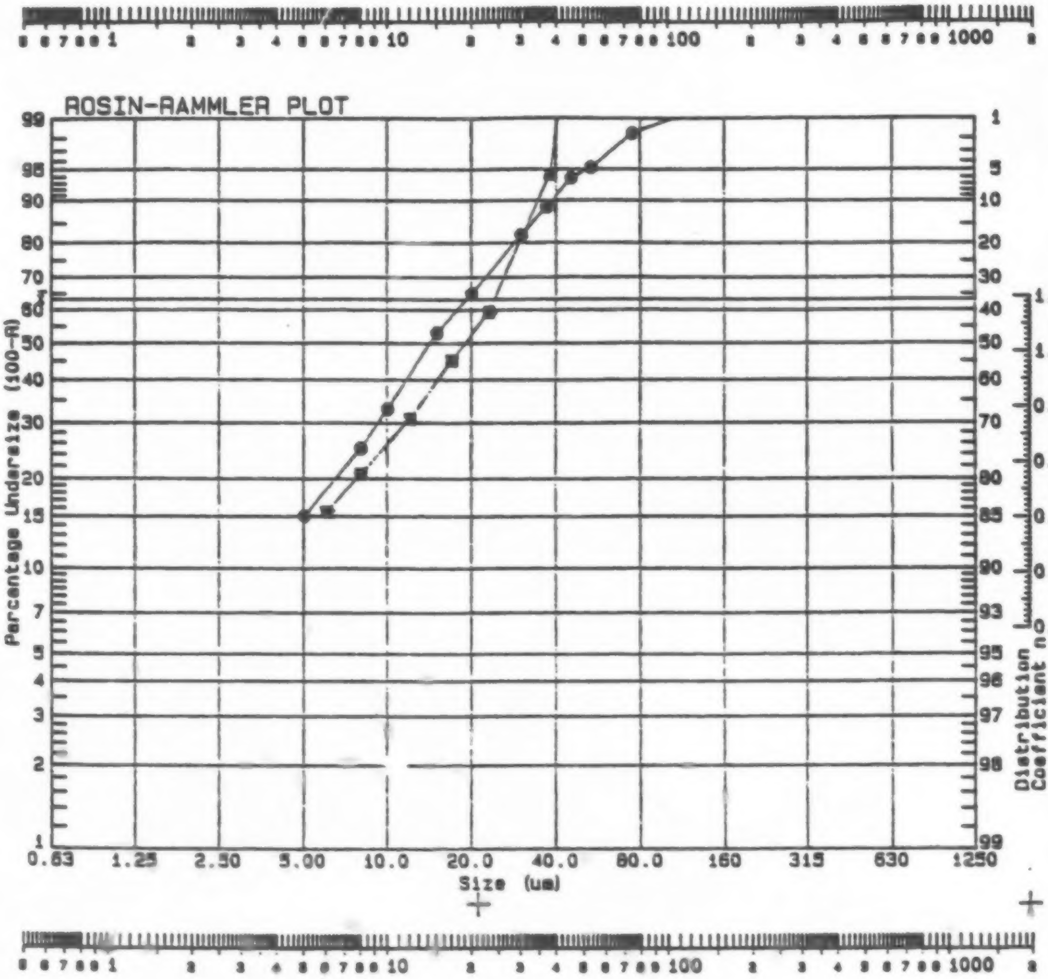
Maitland Laboratory

APPENDIX 8

AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.

SIZE ANALYSIS 17-FEB-88



LEGEND

■ Kilborn Engineering: Sample No. 4 Size Analysis
● Steetley Ultrafine Magnetite

APPENDIX 9

Report No. 09/1434
Date : February 11, 1986

Client	:	Kilborn Engineering (B.C.) Ltd.
Report to	:	Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 5

SIZE ANALYSIS

SIZE (millimetres)	FRACTIONAL %	CUMULATIVE %	
	Retained	Retained	Passing
* 0.053	0	0	100
* 0.045	0	0	100
* 0.038	1.9	1.9	98.1
0.023	39.3	41.2	58.8
0.017	14.7	55.9	44.1
0.012	13.3	69.2	30.8
0.008	9.5	78.7	21.3
0.006	5.2	83.9	16.1

Analyses carried out using a Warman Cyclosizer unit except for those marked (*), which were carried out using Wet Sieve Analysis.

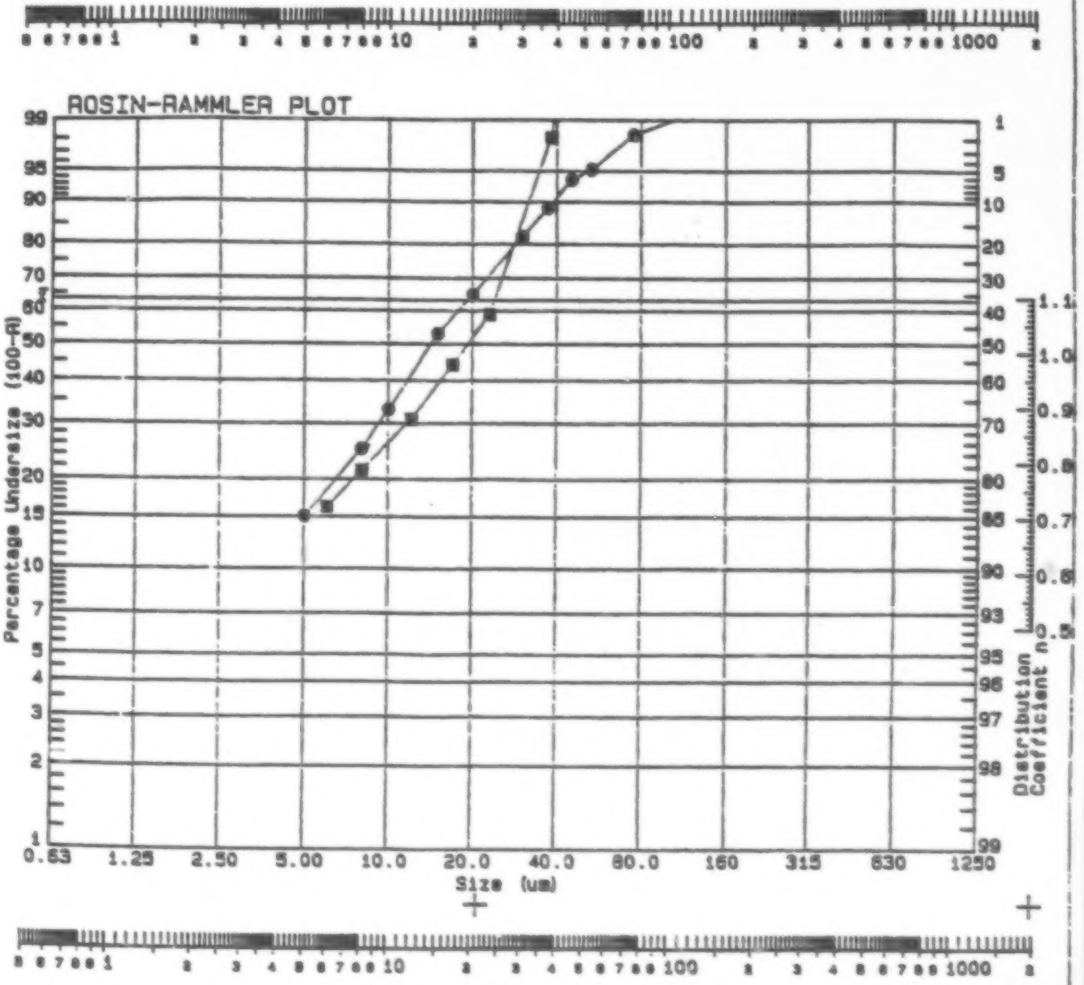
A. C. I. R. L.
Maitland Laboratory

APPENDIX 10

AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.

SIZE ANALYSIS

17-FEB-88



LEGEND

■ Kilborn Engineering: Sample No. 5 Size Analysis
● Steetley Ultrafine Magnetite

APPENDIX 11

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 6

SIZE ANALYSIS

SIZE (millimetres)	FRACTIONAL % Retained	CUMULATIVE % Retained	CUMULATIVE % Passing
* 0.053	0	0	100
* 0.045	0.2	0.2	99.8
* 0.038	5.7	5.9	94.1
0.023	30.5	36.4	63.6
0.017	13.0	49.4	50.6
0.012	14.0	63.4	36.6
0.008	7.9	71.3	28.7
0.006	6.3	77.7	22.3

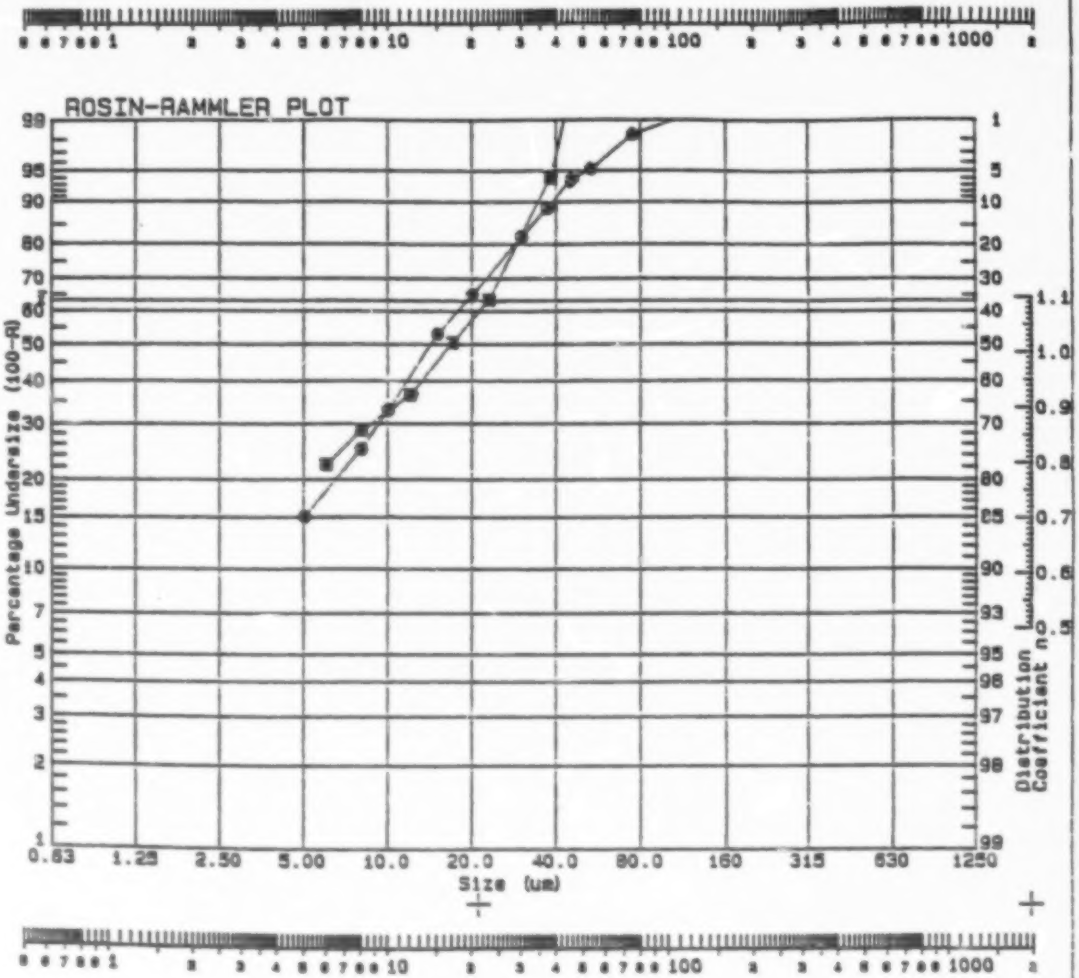
Analyses carried out using a Warman Cyclosizer unit except for those marked (*), which were carried out using Wet Sieve Analysis.

....
A. C. I. R. L.
Maitland Laboratory

APPENDIX 12

ACIRL AUSTRALIAN COAL INDUSTRY RESEARCH LABORATORIES LTD.

SIZE ANALYSIS 17-FEB-86



LEGEND

■ Kilborn Engineering: Sample No. 6 Size Analysis
● Steetley Ultrafine Magnetite

APPENDIX 13

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 1

Magnetometer Analysis of material sized to - 0.045 + 0.038mm

Initial susceptibility	- k30 (emu/g) =	0.04
	- k30 (m3/kg) =	
Susceptibility at 800 oersteds	- k800 (emu/g) =	0.05
	- k800 (m3/kg) =	
Saturation Moment	- Msat (emu/g) =	81
	- Msat (Am2/kg)=	
Coercive Force	- Hc (oersteds)=	33
	- Hc (A/m) =	

Notes: Susceptibility - 0.010 gauss/g/oersted = 1.256x10-4 m3/kg
Saturation Moment - 1 gauss/g = 1 Am2/kg
Coercive Force - 1 oersted = 80 A/m

....
A. C. I. R. L.
Maitland Laboratory

APPENDIX 14

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 2

Magnetometer Analysis of material sized to - 0.045 + 0.038mm

Initial susceptibility	- k30 (emu/g) =	0.01
	- k30 (m3/kg) =	
Susceptibility at 800 oersteds	- k800 (emu/g) =	0.03
	- k800 (m3/kg) =	
Saturation Moment	- Msat (emu/g) =	41
	- Msat (Am2/kg) =	
Coercive Force	- Hc (oersteds) =	65
	- Hc (A/m) =	

Notes: Susceptibility - 0.010 gauss/g/oersted = 1.256x10-4 m3/kg
Saturation Moment - 1 gauss/g = 1 Am2/kg
Coercive Force - 1 oersted = 80 A/m

A. C. I. R. L.
Maitland Laboratory

APPENDIX 15

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 3

Magnetometer Analysis of material sized to - 0.045 + 0.038mm

Initial susceptibility	- k30 (emu/g) =	0.04
	- k30 (m3/kg) =	
Susceptibility at 800 oersteds	- k800 (emu/g) =	0.05
	- k800 (m3/kg) =	
Saturation Moment	- Msat (emu/g) =	79
	- Msat (Am2/kg)=	
Coercive Force	- Hc (oersteds)=	63
	- Hc (A/m) =	

Notes: Susceptibility - 0.010 gauss/g/oersted = 1.256x10-4 m3/kg
Saturation Moment - 1 gauss/g = 1 Am2/kg
Coercive Force - 1 oersted = 80 A/m

A. C. I. R. L.
Maitland Laboratory

APPENDIX 16

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 4

Magnetometer Analysis of material sized to - 0.045 + 0.038mm

Initial susceptibility	- k30 (emu/g) =	0.04
	- k30 (m3/kg) =	
Susceptibility at 800 oersteds	- k800 (emu/g) =	0.06
	- k800 (m3/kg) =	
Saturation Moment	- Msat (emu/g) =	82
	- Msat (Am2/kg)=	
Coercive Force	- Hc (oersteds)=	36
	- Hc (A/m) =	

Notes: Susceptibility - 0.010 gauss/g/oersted = 1.256x10-4 m3/kg
Saturation Moment - 1 gauss/g = 1 Am2/kg
Coercive Force - 1 oersted = 80 A/m

....
A. C. I. R. L.
Maitland Laboratory

APPENDIX 17

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 5

Magnetometer Analysis of material sized to - 0.045 + 0.038mm

Initial susceptibility	- k30 (emu/g) =	0.05
	- k30 (m3/kg) =	
Susceptibility at 800 oersteds	- k800 (emu/g) =	0.06
	- k800 (m3/kg) =	
Saturation Moment	- Msat (emu/g) =	89
	- Msat (Am2/kg)=	
Coercive Force	- Hc (oersteds)=	20
	- Hc (A/m) =	

Notes: Susceptibility - 0.010 gauss/g/oersted = 1.256x10-4 m3/kg
Saturation Moment - 1 gauss/g = 1 Am2/kg
Coercive Force - 1 oersted = 80 A/m

....
A. C. I. R. L.
Maitland Laboratory

APPENDIX 18

Report No. 09/1434
Date : February 11, 1986

Client : Kilborn Engineering (B.C.) Ltd.

Report to : Mr. D.G. Osborne

MAGNETITE SAMPLE - SAMPLE NO. 6

Magnetometer Analysis of material sized to - 0.045 + 0.038mm

Initial susceptibility	- k30 (emu/g) =	0.05
	- k30 (m3/kg) =	
Susceptibility at 800 oersteds	- k800 (emu/g) =	0.06
	- k800 (m3/kg) =	
Saturation Moment	- Msat (emu/g) =	87
	- Msat (Am2/kg)=	
Coercive Force	- Hc (oersteds)=	25
	- Hc (A/m) =	

Notes: Susceptibility - 0.010 gauss/g/oersted = 1.256x10-4 m3/kg
Saturation Moment - 1 gauss/g = 1 Am2/kg
Coercive Force - 1 oersted = 80 A/m

A. C. I. R. L.
Maitland Laboratory

APPENDIX 'C'

SIZE DISTRIBUTION DATA OF EDMONTON COAL RESEARCH LABORATORY

NOT AVAILABLE

APPENDIX 'D'

STABILITY INDEX TEST METHOD

TRANSLATION - REPORT NO. 44 1336

EVALUATION OF MAGNETIC HEAVY MEDIA AND SUSPENSIONS

[FMPE, The Coal Scientific Research Institute, Ostrava, Radvanica, Czechoslovakia]

This Standard is valid for basic laboratory evaluation of magnetic heavy media and suspensions.

I. GENERAL CRITERIA

1. For Magnetic Heavy Media and Suspensions will be established:

   (a) Volumetric and mass concentration of heavy media by calculation.

   (b) Granular composition of heavy media.

   (c) Stability index of suspension.

   (d) Magnetic contingent capacity (content of magnetic particles).

   (e) Viscosity of suspension.

   (f) Relative permeability.

   (g) Ratio (relation) FeO : Fe_2O_3.

II. DETERMINATION OF VOLUMETRIC AND MASS CONCENTRATION OF HEAVY MEDIA BY CALCULATION

2. (a) Volumetric concentration X in percentage: (%)

$$X = \frac{\gamma - \gamma_2}{\gamma_1 - \gamma_2} .100$$

(b) Volumetric concentration X' in volume units per one litre of suspension:

$$X' = \frac{\gamma - 1}{\gamma_1 - 1} .100 \qquad (ml.l^{-1})$$

γ = Required density of suspension in $g.cm^{-3}$
γ_1 = Density of heavy media in $g.cm^{-3}$
γ_2 = Density of water in $g.cm^{-3}$.

3. (a) Mass concentration of suspension in mass units ($g.dm^{-3}$):

$$\nu = X'.\gamma_1 = \gamma_1 \frac{\gamma - 1}{\gamma_1 - 1} .1000 \qquad (g.1^{-1})$$

(b) Mass concentration ν' in percentage:

$$\nu' = \frac{\nu}{\gamma.1000} .100 = \frac{\nu}{\gamma.10} \qquad (\%)$$

III. DETERMINATION OF HEAVY MEDIA GRANULAR COMPOSITION

4. Heavy media granular composition with grain smaller than 60 microns is done on sedimentation scales type 'SARTORIUS'. Operating and results evaluation instructions are included with the apparatus handbook. Measuring and evaluation is done at VVUU (Coal Scientific Research Institute) - Dressing centre, these scales are installed.

IV. DETERMINATION OF SUSPENSION STABILITY INDEX

5. Suspension Stability Index is established (determined) as follows:

Cylinder 60 mm diameter is filled with tested suspension of known density to the height of 360 mm. After thorough mixing by tumbling (inverting) five times with opening closed, cylinder is left standing to settle for 10 minutes. After 10 minutes, top 200 mm of suspension is siphoned (decanted) and its density established.

Stability index is a dimensionless number and is defined from formula:

$$J = \frac{\gamma_p - \gamma 10}{\gamma_p - 1} . 10$$

γ_p = Density of initial suspension ($g.cm^{-3}$)
$\gamma 10$ - Density of top 200 mm layer of suspension after 10 minutes ($g.cm^{-3}$).

6. Suspension stability values:

Unstable suspension: $J > 5$
Semistable suspension: $J = 3 \div 5$
Stable suspension: $J < 3$

Note: Apparatus for establishment of stability index is shown schematically in Appendix 1, Fig. 1.

V. DETERMINATION OF RELATIVE VISCOSITY OF SUSPENSION

7. For measuring and determination of relative viscosity of suspension, Groppl's flow thru viscosimeter is used, as schematically illustrated in Appendix 2, Fig. 2.

8. Cylindrical viscosimeter for non-corrosive material has an overflow rim at top end and conical attachment at bottom end. Whole apparatus is calibrated such that discharge velocity of 250 ml of water at 20°C is 70 seconds.

9. Before measuring, it is necessary to separate particles larger than 0.1 mm ou screen. Viscosity is measured as follows: with bottom discharge opening closed, viscosimeter is filled up with tested suspension until it overflows. Immediately after filling with the test suspension, the bottom discharge is opened and the timer is started. After the whole cylinder is drained, the timer is stopped. Registered time is proportional to a viscosity of suspension.

   Note: When filling cylinder, the discharge opening can be blocked with pointed wooden or metal rod guided through the bottom opening of the viscosimeter or by finger.

10. Conversion of discharge duration to pascal seconds is done by the following formula:

$$\eta = \frac{\gamma\ (0.0298\ .\ Tkor - 0.878)}{36.83\ .\ \log Tkor}\ .10^{-2} \qquad (Pa.s)$$

γ = Suspension density
T = Duration of suspension discharge in seconds

$$Tkor = \frac{T^3}{772}$$

   Note: For comparison - water viscosity at 20°C is 10^{-3} Pas.

11. Maximum suspension viscosity value not endangering proper separation is 14.10^{-3} Pas.

VI. DETERMINATION OF MAGNETIC CONTINGENT

12. Determination of magnetic contingent (particles) volume (content) is done by using 'MAG-MINI' instrument, developed by OKR (Ostrava-Kervina Mining District) - Automization and Mechanization Department, Regional Administration District - Ostrava. Operating instructions for measuring and evaluation of results is included in this instrument's handbook (prospectus). This instrument may also be used to determine heavy media losses on products by means of measuring the sediment after test by washing and data gained using

measuring apparatus are applied to the mass (density) of the sample removed.

13. Necessary amount of specimen to determine magnetic contingent with a degree of accuracy for average magnetic contingents 1-E = 0.95 and arbitrary selected error W=4 ÷ 4.5% is n=3.

VII. DETERMINATION OF RELATIVE (PROPORTIONAL) MAGNETIC PERMEABILITY

14. Magnetic permeability is reciprocal value of magnetic potential (quantity). Dependency of magnetic power (potential) on medium is measured by a permameter.

15. Measurement is done by indirect comparison method with a magnetite specimen of known permeability to be (determined) assessed as 1.

16. Measuring instrument - permameter - consisting of self-induction coil bridge supplied with alternate current 50 cycles .5^{1}.

17. Bridge is made up of two coils. One with permanent induction and the other - measuring coil - with variable induction dependent on inserted magnetic heavy media specimen.

18. Bridge is in equilibrium if both coils are without core. By inserting specimen into one coil, the equilibrium of the bridge is upset. Current triggered by breaking equilibrium is measured by a milliamperemeter.

19. Specimen for assessment (determination) of permeability must not contain larger particles than 0.5 mm. It is necessary to properly dry specimen before measuring.

20. After assessment of permeability with interval of reliability 1-E = 0.95 and maximum error W = 0.0 4, it is necessary to take a number of specimens n = 3 of such density, so that after averaging to create specimen for permeability measurement.

VIII. MEASURING PROCEDURE

21. After switching on, the milliamperemeter is set to zero. Known 100 g calibrated specimen in calibrated container is inserted into one coil. The milliamperemeter's indicator is set to 100.

22. The gauged container is substituted with a measured specimen.

23. Deviation A on the milliamperemeter is registered and total mass (density) of specimen 'G' is established (determined).

24. Mass (density) of tested specimen magnetic particles M is calculated by formula:

$$M = \frac{G.M_p}{100} \quad (g)$$

M = Mass (density) of tested specimen magnetic ;particles (g)
G = Total mass (density) of tested specimen (g)
M_p = Percentage of known magnetic contingent.

25. Relative permeability μ of heavy media is calculated, such that deviation 'A' registered on milliamperemeter is divided by mass (density) of magnetic particles 'M' of tested specimen.

$$\mu = \frac{A}{M}$$

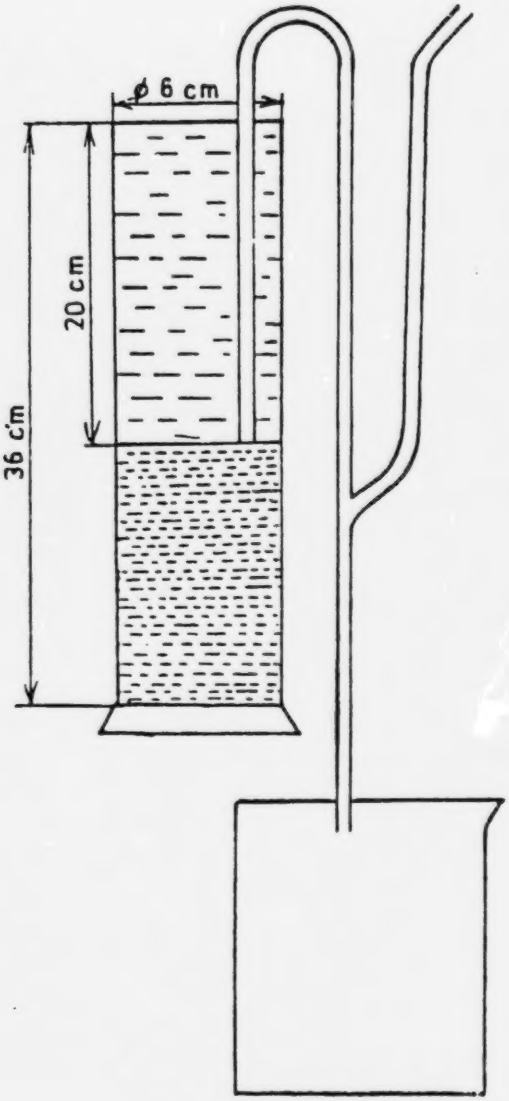
26. Difference of two tests of one specimen must not exceed ± 5%.

References

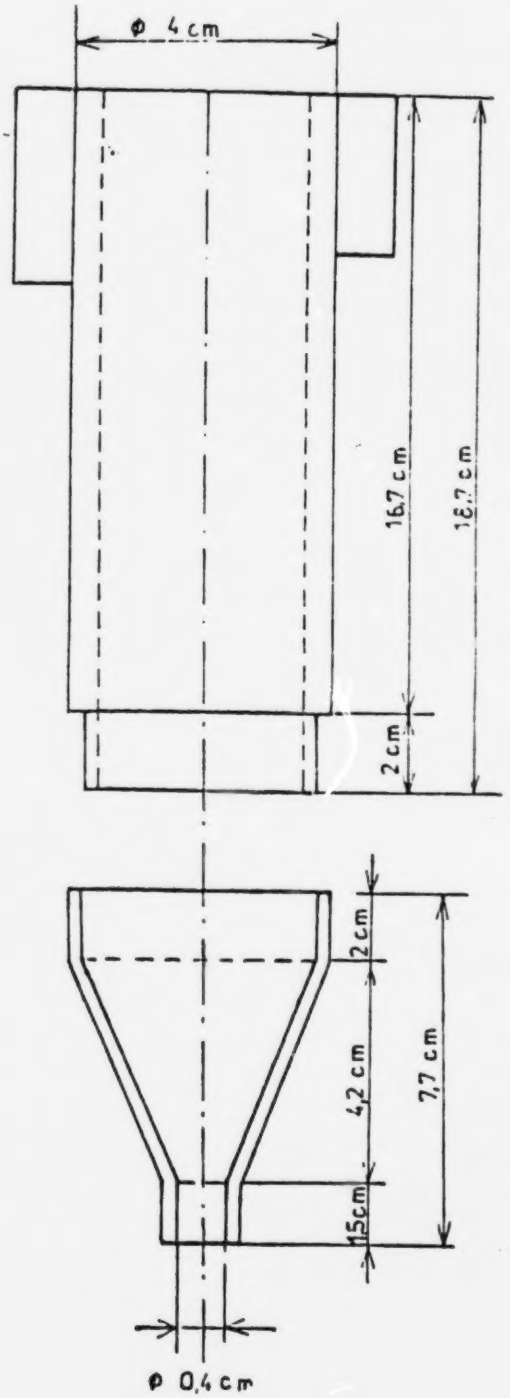
Associated (reference) Standards.

CSN 01 5110	Sampling of Materials.
CSN 01 5111	Sampling of Loose and Granular Materials.
ON 44 1337	Evaluation Methods of Economical Coal Dressing Effectiveness and Regulations for Guarantee Testing (Sampling) Execution.

PŘÍLOHA 1


ø 6 cm
20 cm
36 cm

Obr. 1.


ϕ 4 cm
16,7 cm
18,7 cm
2 cm
2 cm
4,2 cm
7,7 cm
1,5 cm
ϕ 0,4 cm

Obr. 2.

KILBORN

DESIGN CALCULATION NO.

AREA	SECT.	NO.
	–	–

CLIENT EDMONTON COAL RESEARCH LABORATORY
SHEET No 1 OF 2
PROJECT MAGNETITE STUDY
PROJ. No. 7814
DATE 21.3.86 BY DGO
AREA MAGNETITE STABILITY
DIV. No. 15
CHECKED
SUBJECT CZECH. STABILITY INDEX TEST METHOD
REF. DWG. No.

INTRODUCTION

THE FOLLOWING METHOD WAS DEVELOPED FOR USE WITH HEAVY MEDIA SUSPENSIONS AND IS IN REGULAR USE BY THE COAL MINING INDUSTRY IN CZECHOSLOVAKIA. IT WAS DEVELOPED BY THE COAL RESEARCH INSTITUTE OF OSTRAVA. IN 1981 AND PUBLISHED AS PART OF A STANDARD "EVALUATION OF MAGNETIC HEAVY MEDIA SUSPENSIONS" REPORT № ON 44 1336 (30.9.1981)

EQUIPMENT

THE TEST APPARATUS IS SHOWN IN THE ATTACHED DIAGRAM IT COMPRISES A 60 mm DIA. BY 360 mm SETTLING CYLINDER AND A DECANTING PIPE. A TIMER IS ALSO REQUIRED.

METHOD

1. FILL THE CYLINDER WITH THE TEST SUSPENSION (AFTER DE-MAGNETIZATION UNDER NORMAL CIRCUMSTANCES)
2. MIX BY INVERTING THE CYLINDER 5 TIMES.
3. LEAVE TO STAND FOR 10 MINUTES
4. DECANT 200 mm OF SUPERNATANT LIQUID
5. DETERMINE RELATIVE DENSITY

CALCULATION OF STABILITY INDEX

STABILITY INDEX, J IS DETERMINED FROM

$$J = \frac{\gamma_p - \gamma_{10}}{\gamma_p - 1} \cdot 10$$

where

γ_p = INITIAL RELATIVE DENSITY $g.cm^{-3}$

γ_{10} = RELATIVE DENSITY OF SUPERNATANT AFTER 10 MINUTES (ie. top 200mm)

REFERENCE STANDARD

POOR STABILITY $J > 5$ (unsuitable)

REASONABLE STABILITY $J = 3-5$ (acceptable)

GOOD STABILITY $J < 3$ (desirable)

KILBORN

DESIGN CALCULATION NO.

AREA	SECT.	NO.
	–	–

CLIENT EDMONTON COAL RESEARCH LABORATORY
SHEET No 2 OF 2
PROJECT MAGNETITE STUDY
PROJ. No. 7814
DATE 21·3·86 BY DGO
AREA MAGNETITE STABILITY
DIV. No. 15
CHECKED
SUBJECT CZECH. STABILITY INDEX TEST METHOD
REF. DWG. No.

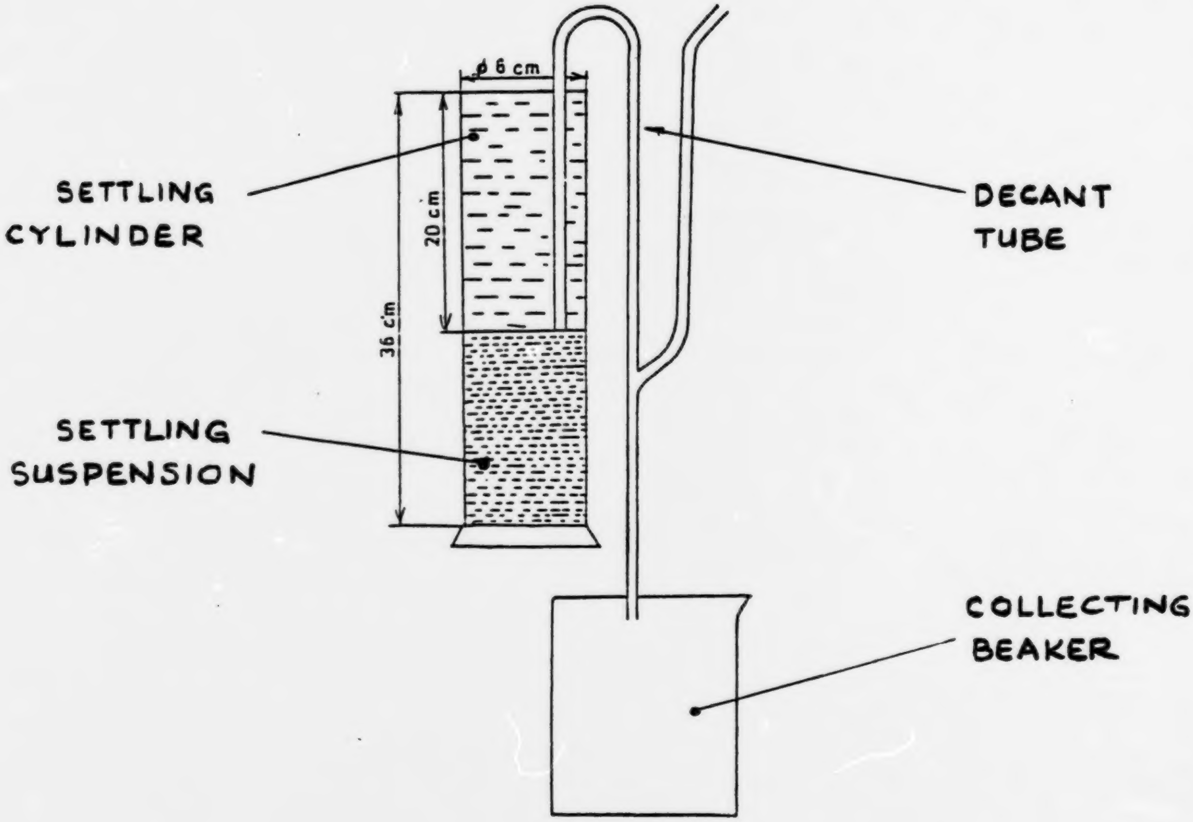

ø 6 cm
20 cm
36 cm
SETTLING CYLINDER
DECANT TUBE
SETTLING SUSPENSION
COLLECTING BEAKER

DIAGRAM of TEST APPARATUS

HEAVY MEDIA SUSPENSION
STABILITY INDEX TEST

SOURCE FMPE NO ON 44 1336

APPENDIX 'E'

QUESTIONNAIRE

CHARACTERISTICS OF CANADIAN MAGNETITE RESOURCES FOR OPTIMUM UTILIZATION IN COAL MEDIUM PROCESSES

QUESTIONNAIRE

Magnetite Supplier(s): ____________________
(Name and Address)
____
____
____
____

Cost Per Tonne Delivered to Mine Site: ____________________
(or other basis)
____

Quotations From Other Potential Suppliers:

Name	Cost

Method of Storage and Handling (include a simple flowsheet, if possible):
____
____
____
____

Storage Capacity at Plant Site: ____________________ Tonnes
Minimum Inventory Required: ____________________ Tonnes
Annual Magnetite Consumption: ____________________ Tonnes

Specification of Supplied Magnetite:

Percent Magnetics Content, greater than: ____________________ %

Percent Iron Content: ____________________ %

Percent Minus 45 Microns (325 Mesh): ____________________ %

Percent Total Moisture: ____________________ %

Percent Non-Magnetics: ____________________ %

Density: ____________________

Other Characteristics: ____________________

Number of Shipments Per Annum: ____________________

Method of Transportation: ____________________

____

Mode of Supply (Bulk, Bag, etc.): ____________________

Number of Quality Tests Per Annum: ____________________

Quality Analysis in Plant and/or
Outside (Commercial) Laboratory: ____________________

____

Type of Test Used for Plant Quality Analysis:

Sizing: ____________________

Method and Sieve Sizes: ____________________

____

____

Magnetic Content: ____________________

Method: ____________________

____

____

Percent Total Moisture: ____________________ %

Method: ____________________

____

____

Density: ______________________________

Method: ______________________________

____

____

Settling Rate (Stability): ______________________________

Method: ______________________________

____

____

Ease of Demagnetization: ______________________________

Method: ______________________________

____

____

Is Sample Demagnetized Before Size Analysis?: ______________

Is Medium in Preparation Plant Tested for Settling, Method?: ______________

Number of Tests Per Month: ______________

General Comments Regarding Quality:

____

____

____

____

____

Type of Analysis for Outside Performed Quality Tests:

Sizing, Number of Sieves Reported: ______________

____

Magnetic Content: ______________

Fe Content: ______________

Percent Total Moisture: ______________ %

Percent Non-Magnetics: ______________ %

Density: ______________

Settling Rate: ______________

Ease of Demagnetization: ______________

Other(s): ______________

Is Magnetite Milled at Plant Site?: ______________

Size Consist of Milled Magnetite: ______________

Describe Milling Circuit (include simple flowsheet, if available):

Describe Magnetite Recovery Circuit (include simple flowsheet, if available):

Is there any new equipment under test in your plant in Magnetite Circuits, e.g., Pumps, Magnetic Separators, Instrumentation, Control Devices, Samplers, etc.?:

	Size	Quantity	Manufacturer
Primary Mag. Sep.:			
Secondary Mag. Sep.:			
Scavenger Mag. Sep.:			
Dilute Med. Cyclone:			

Describe General Preparation Process, indicate on enclosed Flowsheet Process Changes:

Dense Medium Circuit Feed Rate ______________________ Tonne/Hour
(Air Dry Basis, or other)

Magnetite Consumption per tonne of feed to the Dense Medium Circuits:

Describe Method(s) Used to Determine Magnetite Consumption:

Where do you think greatest Magnetite Loss is encountered at present?:

Any plans to cut Losses?:

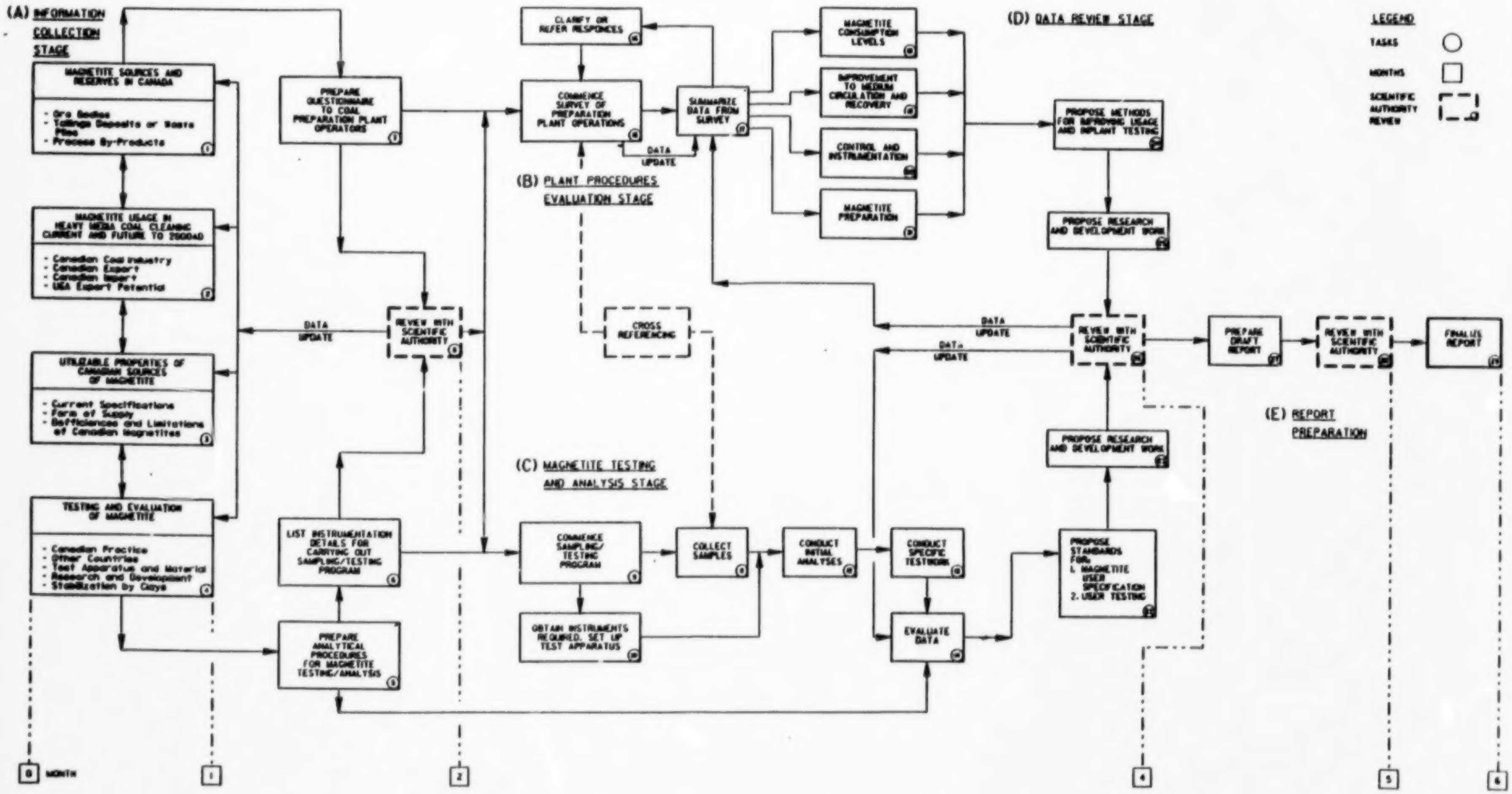
If a Scavenger Magnetic Separator installed, describe Type and Location:

Type:

Location:

APPENDIX 'F'

ACTIVITIES FLOWCHART


(A) INFORMATION COLLECTION STAGE
MAGNETITE SOURCES AND RESERVES IN CANADA
- Ore Bodies
- Tailings Deposits or Waste Piles
- Process By-Products
MAGNETITE USAGE IN HEAVY MEDIA COAL CLEANING CURRENT AND FUTURE TO 2000AD
- Canadian Coal Industry
- Canadian Export
- Canadian Import
- USA Export Potential
UTILIZABLE PROPERTIES OF CANADIAN SOURCES OF MAGNETITE
- Current Specifications
- Form of Supply
- Deficiencies and Limitations of Canadian Magnetites
TESTING AND EVALUATION OF MAGNETITE
- Canadian Practice
- Other Countries
- Test Apparatus and Material
- Research and Development
- Stabilization by Clays
PREPARE QUESTIONNAIRE TO COAL PREPARATION PLANT OPERATORS
DATA UPDATE
REVIEW WITH SCIENTIFIC AUTHORITY
LIST INSTRUMENTATION DETAILS FOR CARRYING OUT SAMPLING/TESTING PROGRAM
PREPARE ANALYTICAL PROCEDURES FOR MAGNETITE TESTING/ANALYSIS
CLARIFY OR REFER RESPONCES
COMMENCE SURVEY OF PREPARATION PLANT OPERATIONS
DATA UPDATE
(B) PLANT PROCEDURES EVALUATION STAGE
CROSS REFERENCING
SUMMARIZE DATA FROM SURVEY
MAGNETITE CONSUMPTION LEVELS
IMPROVEMENT TO MEDIUM CIRCULATION AND RECOVERY
CONTROL AND INSTRUMENTATION
MAGNETITE PREPARATION
(D) DATA REVIEW STAGE
PROPOSE METHODS FOR IMPROVING USAGE AND INPLANT TESTING
PROPOSE RESEARCH AND DEVELOPMENT WORK
DATA UPDATE
DATA UPDATE
REVIEW WITH SCIENTIFIC AUTHORITY
(C) MAGNETITE TESTING AND ANALYSIS STAGE
COMMENCE SAMPLING/TESTING PROGRAM
OBTAIN INSTRUMENTS REQUIRED, SET UP TEST APPARATUS
COLLECT SAMPLES
CONDUCT INITIAL ANALYSES
CONDUCT SPECIFIC TESTWORK
EVALUATE DATA
PROPOSE STANDARDS FOR: 1. MAGNETITE USER SPECIFICATION 2. USER TESTING
PROPOSE RESEARCH AND DEVELOPMENT WORK
PREPARE DRAFT REPORT
REVIEW WITH SCIENTIFIC AUTHORITY
FINALIZE REPORT
(E) REPORT PREPARATION
LEGEND
TASKS ○
MONTHS □
SCIENTIFIC AUTHORITY REVIEW
0 MONTH
1
2
4
5
6

CLIENT: SUPPLY AND SERVICES, CANADA
LOCATION: COAL RESEARCH LAB., EMR., CANMET

KILBORN

TITLE
ACTIVITIES FLOWCHART FOR
DETERMINATION OF CHARACTERISTICS
OF CANADIAN MAGNETITE RESOURCES
FOR OPTIMUM UTILIZATION IN
COAL HEAVY MEDIA PROCESSES

REVISIONS

REFERENCE DRAWINGS